JANUARY 1960

NUCLEONICS

ATOMIC POWER • NUCLEAR ENGINEERING • APPLIED RADIATION

THE NUCLEAR SIXTIES:

COMPETITIVE POWER

This decade will bring it to the U. S.

For views of a distinguished panel, see p. 68

McGraw-Hill Publication • One Dollar

Hamner – 20th CENTURY

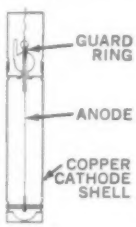
BF_3 PROPORTIONAL COUNTERS

for Extreme Sensitivity and High Resolution in Neutron Counting

These BF_3 Proportional Counters employ the B^{10} (n, α) reaction for the detection of thermal neutrons. Excellent characteristics are obtained, combining high detection efficiency with excellent discrimination against γ radiation. They are designed for use under total irradiation conditions, or alternatively, with collimated beams of neutrons incident at one end of the counter. The maximum gamma flux in which these counters can be employed is 10^4R/hr and the maximum counting rate which can be expected from the tubes is 10^5 counts/sec. The life of the counter is in excess of 10^{10} counts and this can be increased by operating the counter at as low a gas multiplication as is permitted by the associated equipment. For cases where several counters are to be used in parallel, only very slight adjustment in the high voltage supplied to each is required to produce equal output pulse heights.

CONSTRUCTION

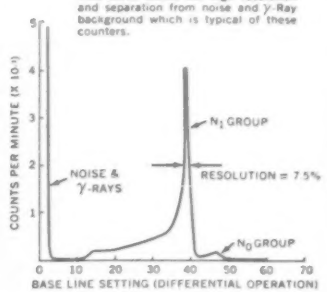
The counters are of metal construction, thin walled copper being employed to minimize neutron capture. A cylindrical body forms the cathode with an anode connection brought out one end via a glass-metal seal. The body of the counter surrounding the glass-metal seal is threaded to facilitate the attachment of terminations to suit the equipment employed.



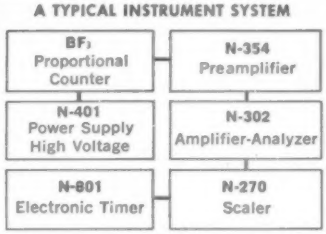
TYPE	Diameter (cms)	Active Length (cms)	Overall Length (cms)	Sensitivity* Counts/sec/ n/cm²/sec
SERIES EB				
5EB40/13	1.3	5	11.5	0.32
28EB40/13	1.3	28	34	1.75
9EB70	2.5	9	18	2.25
12EB20	2.5	12	21	1.5
12EB40	2.5	12	21	3.0
12EB70G	2.5	12	22	5.2
31EB20	2.5	31	41	3.8
31EB40	2.5	31	41	7.6
31EB70G	2.5	31	42	13.5
15EB70/50G	5.0	15	28	27.5
40EB70/50G	5.0	40	54	73.0
84EB45/50G	5.0	84	100	83.5
107EB70/50G	5.0	107	119	196.0
SERIES B				
5B40/13	1.3	5	11.5	0.06
28B40/13	1.3	28	34	0.35
12B20	2.5	12	21	0.3
12B40	2.5	12	21	0.6
12B70G	2.5	12	22	1.04
31B20	2.5	31	41	0.77
31B40	2.5	31	41	1.54
31B70G	2.5	31	48	2.7
15B70/50G	5.0	15	54	5.5
40B70/50G	5.0	40	100	14.6

*Calculated using a measured value of 3.0 cps/n/cm²/sec for type 12EB40
Series B. Counters filled with unenriched BF_3 with an isotopic concentration of 18.8% B^{10}.
Series EB. Counters filled with enriched BF_3 with an isotopic concentration of greater than 90% B^{10}.

This curve shows the high resolution and separation from noise and γ-Ray background which is typical of these counters.



A TYPICAL INSTRUMENT SYSTEM



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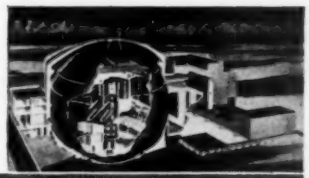
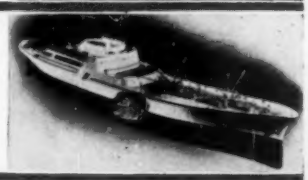
Example • Indian Point, Pressurized Water, Thorium Converter: Design and manufacture of nuclear system



MARINE PROPULSION SYSTEMS

Example • N.S. Savannah: Design and manufacture of nuclear system



MAJOR DEVELOPMENT PROJECTS

Examples • Liquid Metal Fuel Reactor Experiment, Gas Suspension Study

RESEARCH REACTORS

Examples • Hamburg, Germany; Sao Paulo, Brazil

MAJOR NUCLEAR COMPONENTS

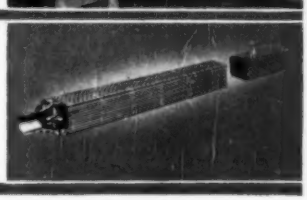
Reactor Vessels • ***Examples*** • **BR-3 Yankee EBWR U.S. Navy**

Heat Exchangers • ***Examples*** • **Shippingport SRE U.S. Navy**

Pressurizers • ***Examples*** • **Yankee U.S. Navy**

FUEL ELEMENTS AND CORES

Examples • Materials Testing Reactor, Engineering Test Reactor, Research Reactors, U.S. Navy



These are but a few examples of the work done by B&W to help release the energy of the atom for useful power. For more information, please write for AEB-8, "B&W and Nuclear Power Development." The Babcock & Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, N. Y.

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APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

JANUARY 1960

VOLUME 18 NUMBER 1

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Tracer Study of Electroplating

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. . . about NUCLEONICS

Our New Publisher

Jerome D. Luntz, who has been Editor of NUCLEONICS since 1953 and Associate Publisher since September of 1958, has been appointed Publisher of NUCLEONICS as of this issue (he continues as Editor). For those of us who work for and with Jerry this is welcome recognition of a job well done. Jerry's association with NUCLEONICS goes back to 1947 and volume 1, number 1. He and NUCLEONICS and the nucleonics industry have been inseparably associated ever since. We know we speak for Jerry's many friends when we say that his new appointment augurs well for the entire nuclear field.

The New Look

There's a new look to NUCLEONICS. We've changed the cover, the contents page and this page. The type style in which our name is carried on the cover (we call it the logotype) has been converted from the hand-lettered special face that served us so well over the years to a more modern extended face called Fortune. More significant to you as a reader is the redesign of the contents page to provide more space for article listings. These changes were not made lightly—we, as you, had grown accustomed to the old contents page and logotype—but there's new utility in the new contents page and the new logo brings a fresh look.

The new broom that is responsible for these changes is shown below. His name is Tom Howland, and he is Nucleonics' new Art Director. Tom comes to us with an impressive background of accomplishments as Associate Art Director of another McGraw-Hill publication and of training at Pratt Institute. We look forward to doing great things together.

TOM HOWLAND, new Art Director

The Nuclear Sixties

There is admittedly a certain arbitrariness to calendar milestones. Certainly the particular phasing that is represented by the Gregorian calendar cannot have fundamental technical significance for, say, the achievement of competitive nuclear power. Nevertheless there is a psychological and a political impact to the beginning of a new decade that is not to be underestimated. Frankly, we're excited about the sixties; we've dubbed them the Nuclear Sixties because we feel that in this decade the nuclear industry is going to come into its own. Read Jerry Luntz's editorial on p. 67 and the account of a special dinner meeting on The Nuclear Sixties that follows it on p. 68. Then see if your own sense of conviction about our bright future is not reinforced. It's going to be a great ten years.

—The Editors

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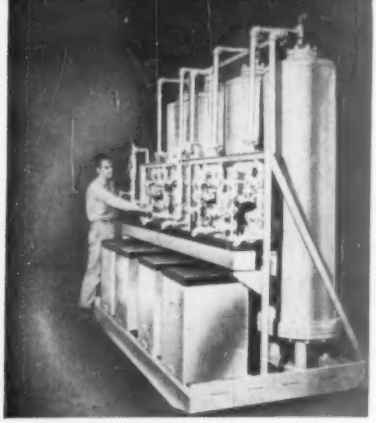

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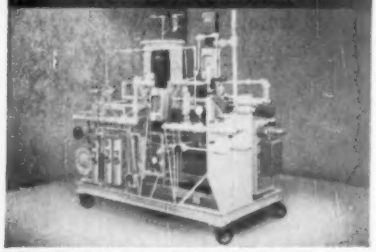

The Cooling Loop (above) maintains ultra pure water at a minimum resistance of 10,000,000 ohms at 25° C. It incorporates a continuous repurification system including oxygen removal, mixed-bed ion exchange, and MF® Sub Micron Filter to remove particles down to 0.45 micron. Write for literature.

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NUCLEAR REACTIONS

British Guaranteed-Price Power

DEAR SIR:

We have read with great interest the article "Westinghouse Offers Guaranteed-Price A-Power" in the October NUCLEONICS (p. 17).

Mitchell Engineering has been offering guaranteed-price A-power in the 17.5-60 Mw range for the last 12 months.

Because of the difference in plant capacities, our costs cannot be compared directly. However, on pp. 20 and 21 there are estimates prepared for the U. S. AEC on the cost of power produced by 25-, 54-, 20.3- and 160-Mw plants. Above is a tabulation summarizing our costs for 20- and 60-Mw(e) plants; you will see that the final cost of electricity is, in each case, lower than the figures quoted on pp. 20 and 21 of the October issue, although we have probably adopted a more conservative figure on fuel costs since we are prepared to guarantee this under penalty. Our lower costs may also be due to our lower capitalization charges. Nevertheless, we were pleased at the publication of the AEC estimates in that they support the cost data on the nuclear plants that we have been offering for the past year on a guaranteed basis.

The capital cost will be lower than that quoted in America today because of the differential in raw materials and wages.

In the capital costs, it is exceedingly difficult to provide an accurate figure for civil engineering, which, in our wording, covers excavation, foundations, concrete work and buildings. It is our practice to include a lump sum that we estimate will cover this work and to ask for it to be adjusted, up or down, in accordance with local conditions after the site has been finally selected and bore holes sunk.

As far as the core is concerned for each reactor, this has been developed with our associates, AMF Atomics, a division of American Machine & Foundry Company. We have been encouraged by the competitive attitude of the American core fabricators and the degree of cooperation that they have given to us.

Technically, our design differs little from that of other boiling-water reactors, but there are distinct signs of the possibility of technical improvements in the near future.

—G. GORDON JACKSON, Manager
Nuclear Power Division
Mitchell Engineering Ltd.
London, England

Costs of 20- and 60-Mw(e) Plants

	20 Mw(e)	*60 Mw(e)*
Load factor	70%	70%
Gross Mw(e)	21.5	62
Net Mw(e)	20	60
Annual net Mwh	122.7×10^6	368×10^6
Capital cost (£)	3,150,000	6,000,000
Power costs (mills/kwh)		
Mean interest charge at 3½%	2.52	1.64
Depreciation at 5%	3.59	2.28
Total capital charges	6.11	3.92
Fuel costs	4.47	4.28
Maintenance and operation costs at 3% of capital cost of plant	2.16	1.37
Total cost of net electrical power	12.74	9.57

many new developments

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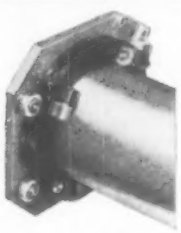
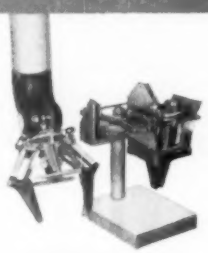
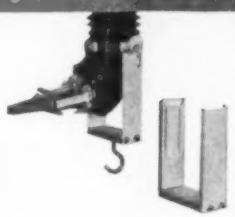


Improved *roller mount:* More rugged, more serviceable, less wear on through tube.

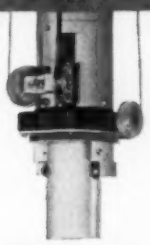


Improved *wrist joint, tong,* and *tong jig:* Greater protection of gears, more rugged, easier interchange.

Improved *handle:* More rugged, more satisfactory control of separation indexing and squeeze motion lock.



Improved *booting* and *load hook: Partial or* complete booting possible, load hook fits on booted or unbooted arm.

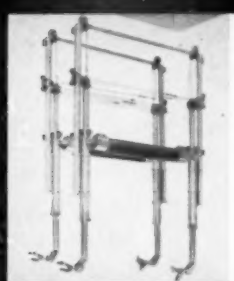


Improved *azimuth assembly:* Eliminates exposed rollers, provides greater "Z" motion or shorter collapsed length.

for thru-wall installation

CRL MODEL 8

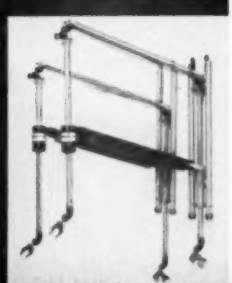
Thru-wall installation for intermediate to high-level shielding. Separation indexing and lateral rotation keeps operator close to window with full visibility over large area. Easy to relocate —one man with a light crane can remove and relocate in less than five minutes.



for over-wall installation

CRL MODEL 4

General purpose — for installation over a barrier wall or through ceiling opening of protective enclosure.



for restricted-space installation

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- Ready to use plug-in unit
- Permanently light sealed
- Capsule design facilitates decontamination
- Close dimensional tolerances
- Harshaw guaranteed

Large Crystal MATCHED WINDOW LINE

(Designed primarily for crystals 4" dia. and larger)

- "Small crystal" performance achieved through improved optical design
- Low mass containers
- Available in standard aluminum or complete low background assemblies
- Convenient mounting flange
- Ready to use

Every Harshaw crystal is a product of our experience in crystal growing technology since 1936

Other Phosphors Available from The Harshaw Chemical Company

ROUGH CUT THALLIUM ACTIVATED SODIUM IODIDE CRYSTAL BLANKS • EUROPIUM ACTIVATED-LITHIUM IODIDE (NORMAL) • EUROPIUM ACTIVATED LITHIUM IODIDE (96% Li^6 ENRICHED) • THALLIUM ACTIVATED CESIUM IODIDE • THALLIUM ACTIVATED POTASSIUM IODIDE • ANTHRACENE • PLASTIC PHOSPHORS

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For Infrared and Ultra Violet Transmitting Optics

"HARSHAW QUALITY" INHERENT IN EACH HARSHAW-GROWN CRYSTAL GUARANTEES THE MOST EFFICIENT OPTICAL TRANSMISSION POSSIBLE THROUGH:

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"HARSHAW QUALITY" meets the demand for uniformity of optical properties such as dispersion and refractive index. Prices, specifications, or other information will be sent in answer to your inquiry.

The following infrared and ultra violet transmitting crystals are available; others are in the process of development:

SODIUM CHLORIDE • SODIUM CHLORIDE MONOCHROMATOR PLATES • POTASSIUM BROMIDE • POTASSIUM BROMIDE PELLET POWDER (through 200 on 325 mesh) • POTASSIUM CHLORIDE • OPTICAL SILVER CHLORIDE • THALLIUM BROMIDE IODIDE • LITHIUM FLUORIDE • LITHIUM FLUORIDE MONOCHROMATOR PLATES • CALCIUM FLUORIDE • BARIUM FLUORIDE • CESIUM BROMIDE • CESIUM IODIDE

Additional information on the physical and optical properties of the above crystals is available in our 36-page booklet "Synthetic Optical Crystals". Send for your free copy.

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Crystal Division • Cleveland 6, Ohio

TRIGA — the General Dynamics inherently safe multi-purpose reactor for training, research, and isotope production — has been selected by the United States Government as an operating feature of the World Agriculture Fair in New Delhi, India, December 11, 1959 to February 14, 1960. Conceived and developed by General Atomic Division of General Dynamics specifically for use by universities, medical centers, and other research institutions, TRIGA has gained worldwide acceptance. Because of their versatility, simplicity, economy, and inherent safety, TRIGA reactors are now in use or soon will be in operation on five of the six continents of the world.

TRIGA GOES TO INDIA

★TRIGA Atomic Reactors Around the World:

EUROPE:
National Committee for Nuclear Research • Rome, Italy
Federal Ministry of Education Atominstitut • Vienna, Austria
International Conference on Peaceful Uses of Atomic Energy 1958 • Geneva, Switzerland (on loan to U.S. Government)

ASIA:
Musashi College of Technology • Tokyo, Japan
National Atomic Research Institute • Seoul, Korea
Institute of Nuclear Research • Dalat, Viet Nam
Rikkyo University • Tokyo, Japan
World Agriculture Fair • New Delhi, India (on loan to U.S. Government)

NORTH AMERICA:
U.S. Veterans Administration Hospital • Omaha, Nebraska
Cornell University • Ithaca, New York
University of Illinois • Champaign-Urbana, Illinois
University of Arizona • Tucson, Arizona
Kansas State University • Manhattan, Kansas
General Atomic Division • San Diego, California

AFRICA:
University of Lovanium • Leopoldville, Belgian Congo

SOUTH AMERICA:
University of Minas Gerais • Belo Horizonte, Brazil

GENERAL ATOMIC
DIVISION OF **GENERAL DYNAMICS**

HTGR gas-cooled reactors for central station power — Maritime gas-cooled reactors — TRIGA reactors — Controlled thermonuclear research — Nuclear power for space vehicles — Basic research in the sciences. Rapid expansion has created openings, including senior positions. Write Box 608, San Diego 12, Calif.

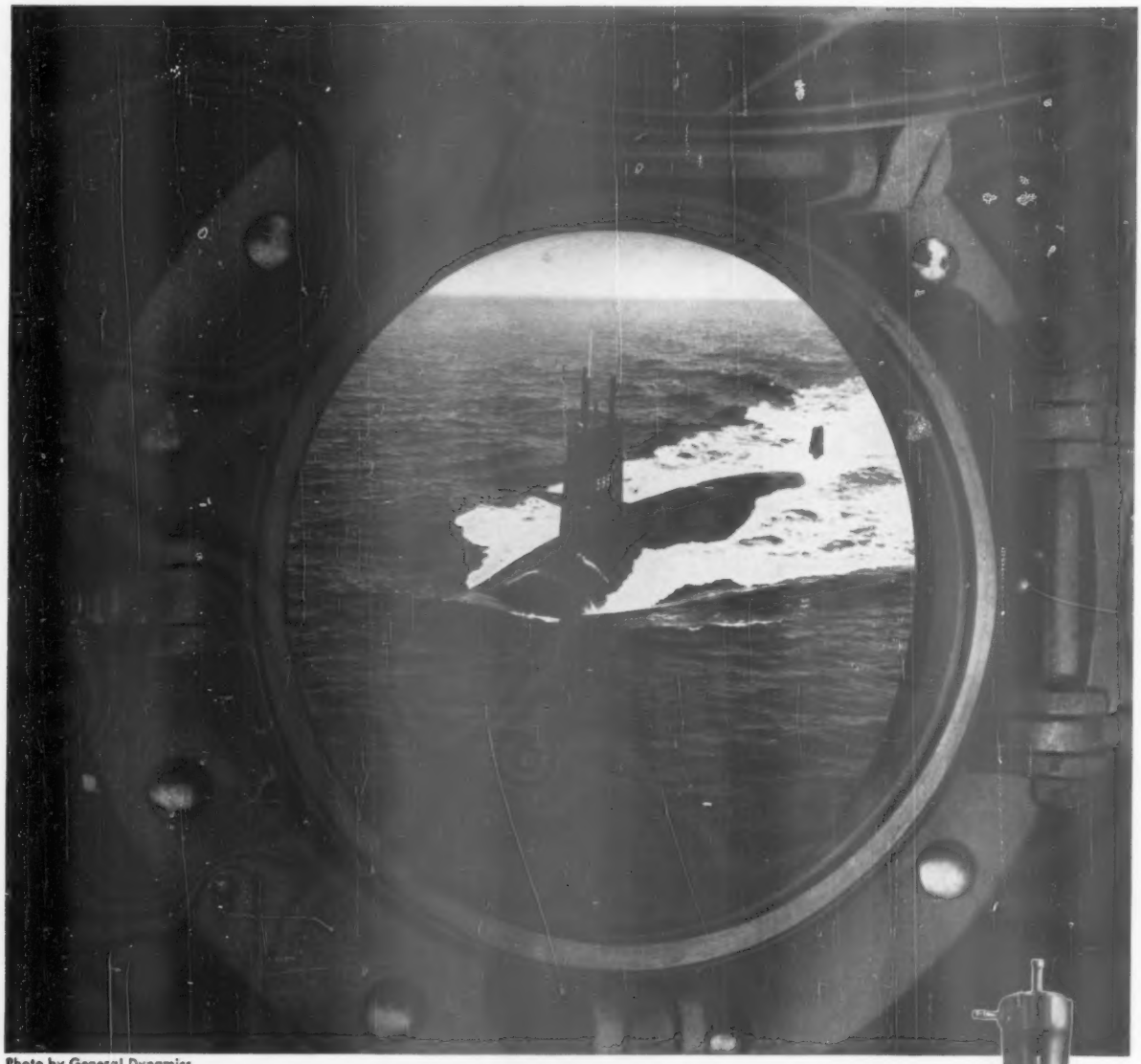


Photo by General Dynamics

IN THE NAVY'S NEW NUCLEAR FLEET

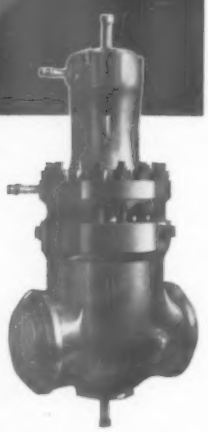
Darling Stainless Steel Valves are "on duty"

Meeting the Navy's rigid specifications for valves in nuclear power plants demands the highest quality and production standards.

Darling is one of the select group of manufacturers supplying stainless steel valves for the Navy's new nuclear submarines. Darling valves are "on duty" on the Skipjack, as well as other nuclear subs still unnamed. These valves incorporate the *exclusive revolving double disc parallel seat* feature... which insures positive sealing and ease of operation.

This Navy acceptance of Darling quality standards holds important implications for designers and builders of commercial atomic power plants. Our know-how and precision manufacturing facilities are at your disposal.

Write us for information, or we'll gladly arrange for a Darling sales engineer to call.



Darling 14" stainless steel gate valve of the type used on the Skipjack.

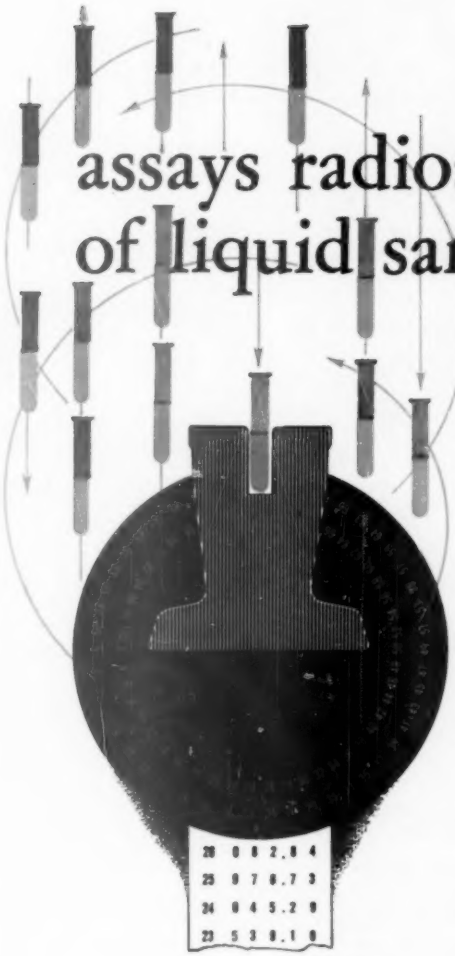
DARLING VALVE & MANUFACTURING CO.

Williamsport 6, Pa.

Manufactured in Canada by Sandilands Valve Manufacturing Co., Ltd., Galt 19, Ont.

DARLING VALVES

assays radioactivity of liquid samples



up to a hundred at a time automatically with accurate count printout

Here's the way to save hours and days in laboratories handling large numbers of radioactive liquid samples (or smaller numbers, maybe, of low-activity samples which count slowly). Answers the kind of problem that arises, for example, in human blood studies with Iron^{59} or in metabolic studies on test animals.

Some of its unique features . . .

Handles 100 15 cc samples

Samples always accessible

Uses virtually any well-type scintillation detector

Operates with Picker Count-and-Time Printer or Printing Timer

Constant background count because samples surround the detector uniformly

Modest cost $2,000.00

spare hours — save the day — with the

PICKER AUTOMATIC WELL COUNTER 2956

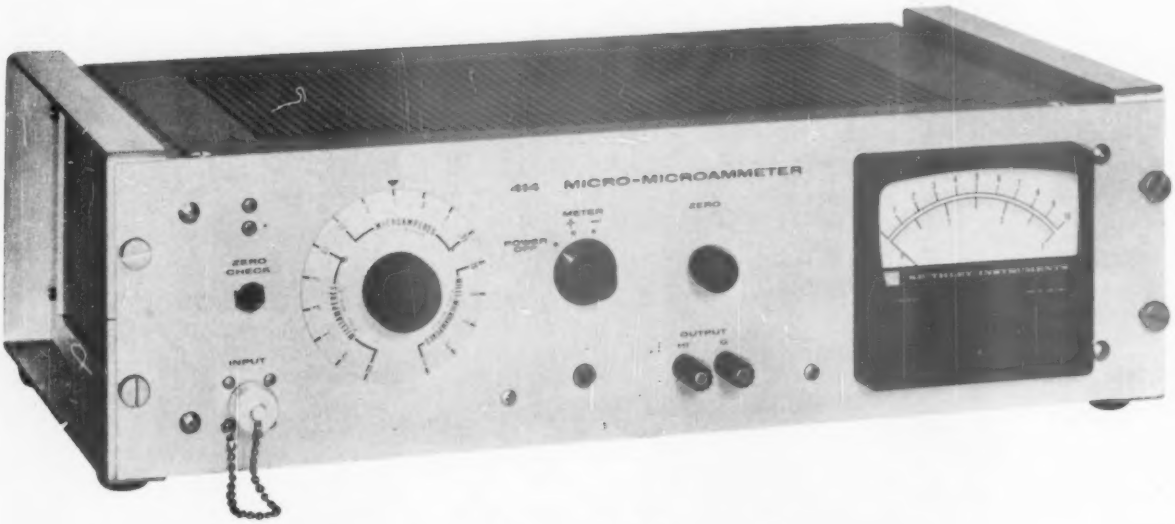
This unique instrument is one of the comprehensive Picker family of quality nuclear equipment. The line includes instrumentation for every phase of diagnostic and therapeutic use of radiosotopes.

For particulars, call any Picker District Office —there's probably one near you (see your local 'phone book). Or write Picker X-Ray Corporation, 25 South Broadway, White Plains, New York.

Picker nuclear

PICKER nuclear instruments

new, low-cost Keithley micro-microammeter



MODEL 414 *offers high performance over 17 ranges for just $280*

Think of the many ways you could use a truly dependable and economical micro-microammeter:

- testing reverse leakages in diodes and transistors, and grid currents in vacuum tubes. The 414 is ideal for many production tests, requiring only manipulation of a single range switch and very infrequent zero checks.
- monitoring and controlling nuclear reactors. The 414 costs less per channel than more complex systems, offers greater dependability and safety because each channel is independent of the others.
- measuring photocell currents, determining radioactivity in "tagged" biological samples, measuring leakages of insulators, resistors, and capacitors. You can convert the 414 for current integration, use it in a thickness gauge, or as an ionization gauge control.

The 414 is built to the same rigid standards as other, more sensitive Keithley products. It is available with a contact meter for go no-go production tests, alarm and control systems.

SPECIFICATIONS

17 RANGES in 1x and 3x steps, from 10 milliamperes to 0.1 milli-microampere full scale.

ACCURACY within ±3% full scale on all ranges down to 10 milli-microamperes, and within 4% on the more sensitive ranges.

INPUT DROP of less than five millivolts on all ranges, with full-scale signals.

RESPONSE TIME of less than 0.5 second on all ranges for any input capacitance up to 5000 micro-microfarads.

ZERO DRIFT of less than 2% of full scale, in any eight-hour period, on any range.

RECORDER OUTPUT of 5 volts with a 1-ma capability.

INPUT CONNECTOR at front; output connectors at both front and back.

DIMENSIONS 19″ x 5¼″ high x 10″ deep. Net weight, 16 pounds.

PRICE $280.00

SEND TODAY FOR COMPLETE DETAILS

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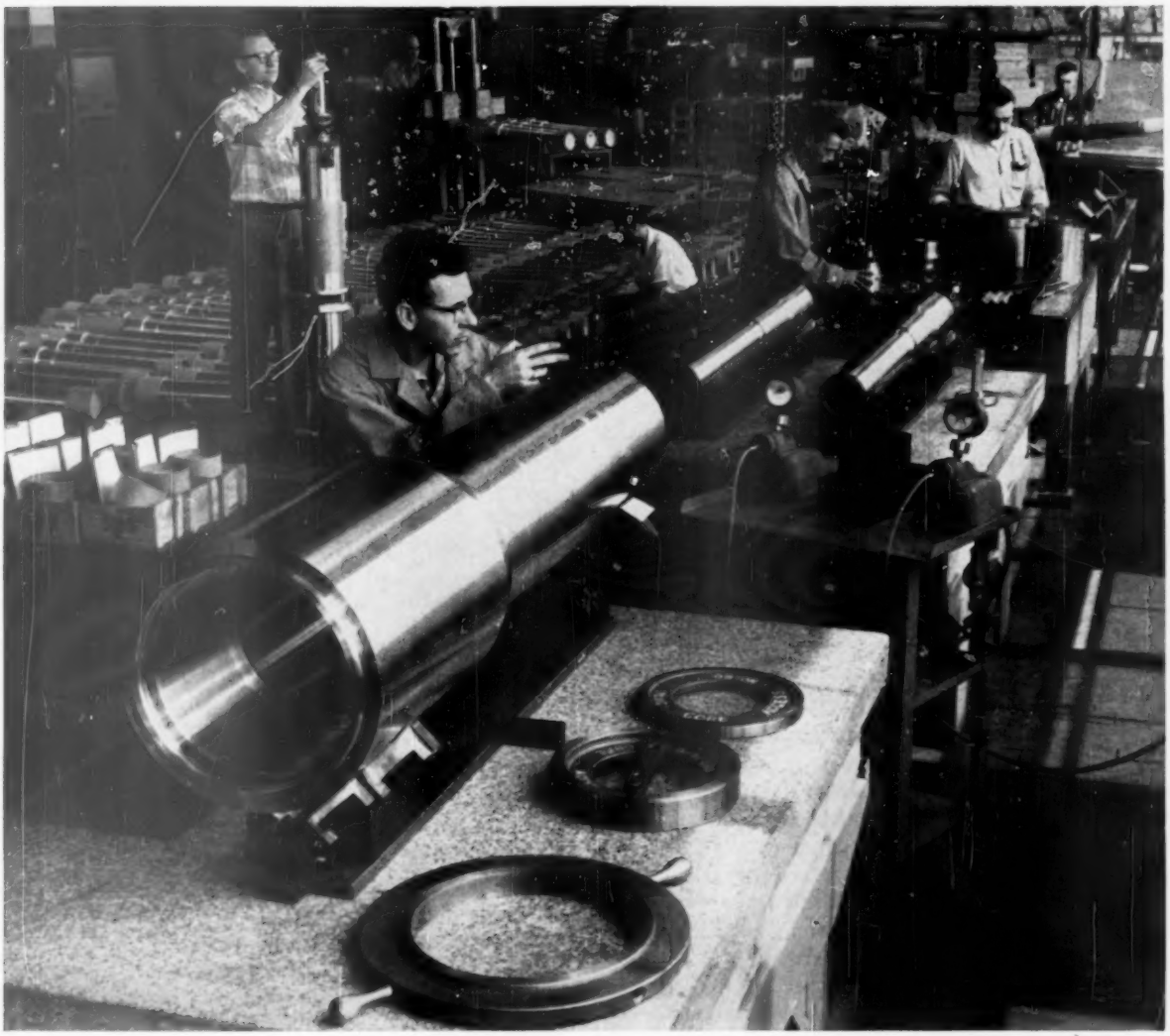
12415 EUCLID AVENUE • CLEVELAND 6, OHIO

SPS RELIABILITY / *A dynamic standard of predictable performance*



SPS Nuclear Division inspector in foreground verifies 12 in. OD of reactor vessel core access housing. Tolerance: ±.001 inch. Precision granite surface plate assures absolutely level test bed, eliminates slightest distortion of jigs. Typical reactor vessel closure head incorporates some 50 of these large precision-machined housings—for control rods, instrument packages and access.

No random sampling here . . .

Parts reaching this final inspection area at the SPS Nuclear Components Division are already documented by detailed records of their dimensions. Presumably they are perfect. Yet to be certain, the records are put aside and every dimension of every part is checked and recorded again—and then cross-checked against the original figures. With a part such as the large core access housing in the foreground, this involves over 200 measurements, many to ±.0005 inch.

To make these checks, SPS technicians draw on more than $3 million worth of precision gaging, including the very latest air and electronic equipment. Most of this is of the comparator type, designed to eliminate possible misreadings, which sometimes occur with vernier scales.

Why this emphasis on perfection? Simply because these parts must function with 100% reliability in locations that are often made inaccessible by radiation. If you have requirements for such components (for reactors or for conventional power-producing machinery), contact SPS—manufacturer of precision threaded fasteners and allied products in many metals, including titanium. Request new Folder 2499.

NUCLEAR COMPONENTS Division **SPS**

JENKINTOWN 45, PENNSYLVANIA

Fused and Ground UO_2 Selected by Hanford for Plutonium Recycle Test Reactor

SPENCER stoichiometric fused and ground uranium dioxide was chosen for the compacted fuel rods of the Hanford Plutonium Recycle Test Reactor.

Compaction densities in the tube have been announced by Hanford as 91% to 92% of theoretical.

Properties of this material are as follows:

1. Uranium dioxide composition: $UO_{2.00\pm}$

2. Particle density: greater than 99.9% of theoretical density, as measured by both X-ray diffraction and standard immersion techniques.

3. Particle size: normally offered in —20 mesh particle size. Special orders may be made in any particle size distribution desired.

4. Typical spectrographic analysis (—20 mesh material):

Element	ppm	Element	ppm
Silver	0.3	Magnesium	30
Aluminum	25	Manganese	20
Boron	0.5	Molybdenum	2
Cadmium	0.1	Nickel	10
Carbon	50	Phosphorus	10
Chromium	10	Lead	5
Copper	5	Silicon	50
Iron	75	Tin	1

5. Availability: laboratory quantities or production quantities. Supplied either from Spencer's original high enrichment plant or from Spencer's new 100,000-pound low enrichment plant.

Also available from Spencer Chemical Company: (1) Ceramic grade uranium dioxide that will sinter to a fired density of 10.5 grams per cc. This material made by continuous process and especially tailored to meet the specifications for your production line. (2) Cermet grade uranium dioxide that has a particle density of greater than 99.9% of theoretical density. This material made from pure crystals of fused UO_2.

For complete details, contact Spencer Chemical Company, Nuclear Fuels Department, Dwight Building, Kansas City 5, Missouri.

SPENCER URANIUM DIOXIDE

Produced by

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Spencer Chemical Company

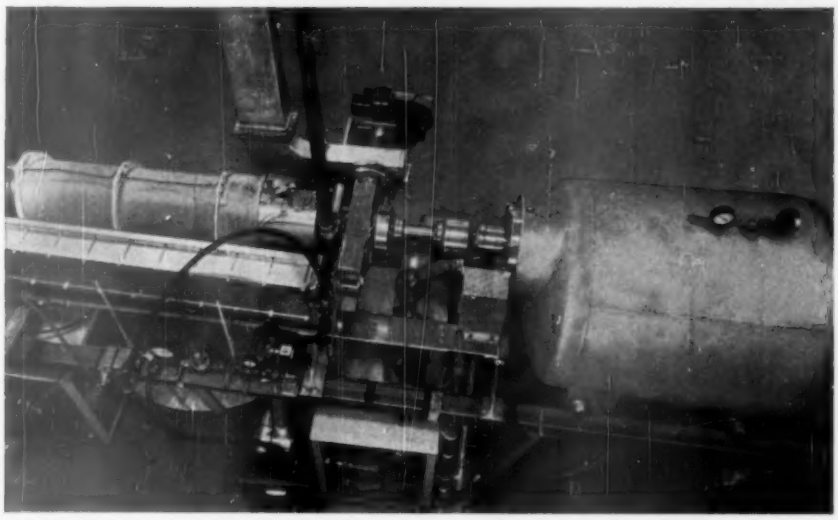
America's Growing Name In Chemicals

General Offices: Dwight Building, Kansas City 5, Missouri

arco APPLIED RADIATION news

The first of a new generation of high power linear accelerators

High beam power at 10 Mev and beyond from ARCO L-band Linac



The ARCO L-band accelerator may be seen in actual operation at ARCO's Walnut Creek, California plant. Come and see it perform.

A new theoretical concept, developed by ARCO physicists, now proved beyond question.

First use of the lower L-band frequencies; higher power at lower cost.

A sweeping redesign of accelerating waveguide structures, radical with respect to conventional approaches.

Dependable Litton Industries L-band klystrons and other high-reliability production model components.

Accumulated experience of the world's largest designer-builder of electron linear accelerators.

Above are the basic ingredients which produced the new high energy, high power ARCO L-band linac—available now for unique experimentation or investigation, or practical, low cost per kw-hr radiation processing.

Data produced during exhaustive theoretical design and experimental testing on the first ARCO L-band machines are so conclusive that construction contracts in excess of $3,000,000 have been awarded for ARCO L-band accelerators.

A major advantage of the new machine is that it is not subject to the limitations (such as pulse shortening) in peak and average beam power levels that have plagued performance of earlier machines. Pulse shortening above the 4 kw level has been eliminated, despite output many times that of previous linacs. Performance of the new L-band machine shows that high power can be obtained even at energies up to 80 Mev.

Purchasers and engineers who have inspected the new ARCO machine believe it will usher in a completely new era in research and processing.

In research, the ARCO L-band machine makes possible exotic physics experiments such as neutron time-of-flight studies using flight paths up to ¼ mile in length. It greatly extends the range of experiments possible in single pulse radiation effects studies. It also permits measurement of transient effects in neutron multiplying assemblies.

In industrial processing, the higher performance and corresponding reduction in cost per kw-hr. are expected to make practical many applications which have looked promising in the laboratory but have been ruled out by high operating costs. Examples are polymerization processes, reforming of petroleum fractions, modification of polymers as in cross-linking, grafting and vulcanizing and commercial production of isotopes.

Data on the new ARCO L-band accelerator awaits your letter. Specific proposals appropriate to your application can be provided quickly and comprehensively. Your inquiry is invited.

ARCO APPLIED RADIATION CORPORATION

World's largest manufacturer of linear electron accelerators

Walnut Creek, California • YEllowstone 5-2250 • Cable "ARCO"

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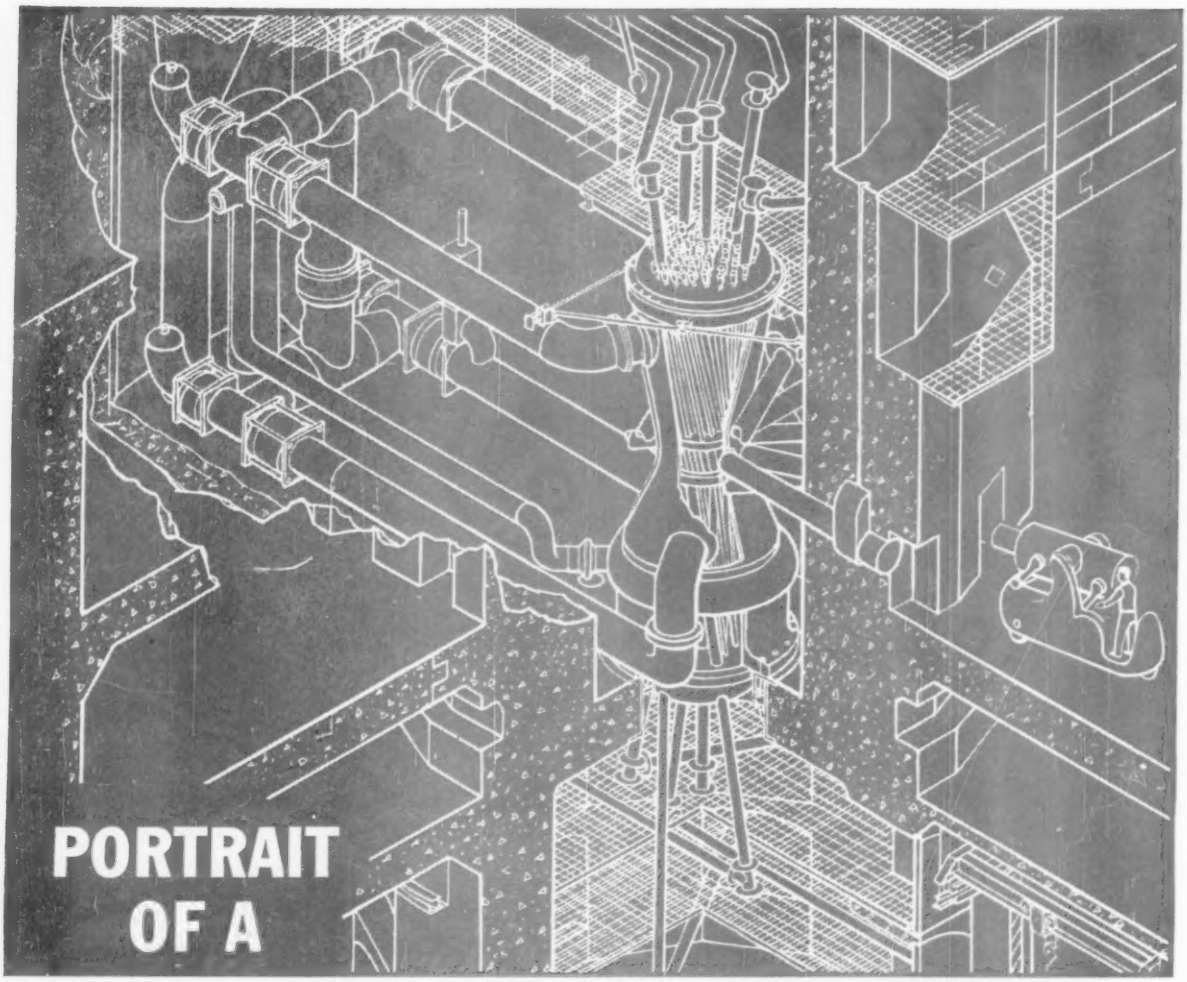


TEST REACTOR

Five nuclear reactors are in various stages of development at NDA. Each differs from the others, but all bear the stamp of true progress.

Progress in design is an NDA hallmark and accounts in part for its success in a demanding field. Equally important, however, is the ability of an organization to move from concept through engineering design, materials development, laboratory experimentation and critical testing. In these, too, NDA's reactors show invention and originality.

NDA's complete reactor capabilities are exemplified in METR (above), a 50-megawatt Materials and Engineering Test Reactor, the first of which is now under construction at Mol, Belgium. Beginning with the core itself, a unique design which combines extremely high neutron flux with simple, independent access to each fuel and experiment tube, METR I will be a vital part of one of the world's great nuclear centers. METR is typical of the family of reactors now under design or development at NDA for power, propulsion and research.

OPPORTUNITIES EXIST AT NDA FOR QUALIFIED SCIENTISTS AND ENGINEERS

a complete reactor company

NDA — **NUCLEAR DEVELOPMENT CORPORATION OF AMERICA**

WHITE PLAINS, N.Y. TEL. WH. 8-5800

NDA EUROPE 31, Rue du Marais, Brussels, Belgium

ROUNDUP of Key Developments in Nucleonics

AEC to Concentrate on Water, Organic Reactors in 60's

The U. S. reactor program enters this month what should be the decade of competitive nuclear power. To assure attainment of this goal, AEC is about to propose formally a sweeping revision in U. S. reactor policy, aimed at giving the utility industry at least three reactor concepts capable of delivering competitive power before the decade is out.

To try to evaluate what lies ahead for the U. S. reactor manufacturing industry in the Sixties, NUCLEONICS has taken a long look at AEC's new reactor policy and its possible consequences for industry.

Germantown Outlook

Abandoning the broad, "pursue-every-promising-concept" approach that has dominated U. S. reactor philosophy since its beginnings, the McCone Commission is near a decision to devote virtually all construction funds for developmental reactors during the next few years to the nation's most advanced concepts: pressurized-water, boiling-water, organic-moderated, and boiling with integral superheat.

This decision—to focus U. S. wealth and manpower on the concepts that will take us to the goal soonest—has been in the cards since the McCone-Pittman regime took hold in the fall of 1958. The Liquid Metal Fueled and Sodium-Deuterium approaches were dropped last winter. Then in June the first outlines of a more-sharply-narrowed program began to appear when AEC launched its effort to lay out a ten-year blueprint (NU, July '59, 17).

The "all-our-eggs-in-as-many-baskets" approach was effectively buried early in November when John McCone told the Atomic Industrial Forum that "Our plan is to select and to support those concepts that we consider the best." Less than a month later the "best" concepts were indicated by the Reactor Development division and its Ad Hoc Committee on Reactor Programs and Policies, as they wound up the staff's exhaustive, six-month inquiry into where the U. S. stands and where it ought to go.

AEC's New Policy

The gist of their recommendations to the Commission:

- Concentrate on water and organic reactors for the high-priority program to reach economic power by the late Sixties.
- Continue a strong program to develop the fast-breeder concept, to meet the national objective of making the best use of our atomic natural resources.
- Continue the research effort to bring around the presently-less-advanced reactor types that potentially might—after a longer development period—prove cheaper than water or organic: gas-cooled, aqueous homogeneous, sodium-graphite, and the Canadian-spearheaded effort on heavy-water natural-uranium reactors.
- Continue likewise to look at promising "blue-sky" reactor ideas, such as are now being aided under AEC's "horserace" program (NU, Oct. '59, 22).

As one high AEC official explains the philosophy of the new policy, "What you have to do is to say to yourself: what are we gaining by spending the large sums of money on all these [eight] that we wouldn't gain by concentrating on one or two or three? We can't afford the luxury of having a lot of good horses. What this probably means is that you look to a system under which you are expecting one or two or three of these contenders to meet the objectives; and that you keep the other ideas in the background, with no construction programs for those others until you have found out that one or two or three are the best contenders."

"[However] I don't think we are going to stop any construction programs now under way."

Figures Tell Story

A study of the AEC cost projections cited by the Commission's reactor development chief, Frank K. Pittman, at the Forum meeting in November (NU, Dec. '59, 21) discloses a quite sharp dividing line between the water and organic systems on one hand, and the less-advanced concepts on the other. Pittman's figures, NUCLEONICS found in juggling them, show that for a relatively small sum and in a rela-

Industry group finds possibility of U^{235} price cuts

An industry committee of three distinguished personalities completed an investigation of AEC's enriched-uranium prices last month and reached this major conclusion: " . . . it is our opinion that in the future the price of U^{235} in terms of 1959 dollars should not increase and a decrease might be warranted."

The inquiry was conducted for the Atomic Industrial Forum (NU, Dec. '59, 19) by Kenneth D. Nichols, former AEC general manager, now a private consultant; Percival F. Brundage, former Budget Bureau director and partner at Price, Waterhouse & Co.; and William Webster, president, New England Electric.

The trio's report made it clear that AEC is in a position to decrease its prices for U^{235} (NU, Oct. '59, 20). There was no discussion of the likelihood of such reductions, however. Two related points were covered: 1. rising interest rates have given the 4% annual use charge "an element of subsidy" and this should be considered "in any contemplated future [price] reduction"; and 2. were weapons production stopped, AEC could absorb any increased costs from only partial operation of its separation plants —no increase in present U^{235} prices would be necessary.

Present enrichment capacity, the report said, can support 40-million kilowatts of commercial nuclear capacity; when additional enrichment plant is needed it could be built for only $20/kw—20–30-million kw for about $500-million.

tively short time, the four most-developed concepts could be made competitive, whereas the others require much more money and much more time. If one totals the moneys listed separately for each concept as being needed to reach the point where a "potential" improved 300-Mw(e) plant could be started, one finds that:

- for $84-million research-development funds and $75-million prototype construction funds—$159-million in all—one could bring to competitiveness the four most advanced concepts (pressurized water, boiling water, boiling with integral superheat, organic moderated) in a period from "the very near future" to 1965.
- it would take $497-million research-development funds and $380-million prototype construction funds —$877-million in all—to make three of the other concepts competitive and the two remaining ones not quite competitive, by a period extending from "late '65 or early '66" to 1971.

The conclusions from this comparison appear obvious, and AEC has obviously drawn them.

Joint Committee's '60 Hearing Calendar

Food Irradiation—late Jan. or early Feb.
Annual '202' Hearings—mid-Feb.
  10-year Reactor Program
  Isotope Development Prog.
Nuclear Frontiers—early March
  Plowshare
  Controlled Fusion
  Nuclear Rocket
Role of National Labs—late March
AEC Authorization Bill—April
Radiation Standards—April
Review of Euratom—unscheduled
Radiation Uses in Biology, Medicine, Agriculture, etc.—unscheduled

Dresden Down Till January; Zircaloy Tube Fault Sought

Resumption of critical testing at Dresden Nuclear Power Station has been put off until mid-January. Reloading of fuel elements had begun Dec. 10 but was interrupted Dec. 13 (and the core unloaded again) when a new difficulty arose with control-rod drive mechanisms, a consequence of the modifications made to eliminate the earlier problem with shear pins. The reactor has been down since Nov. 6, when low-power testing with 54 elements (twice critical mass) had been completed and the core was being built up to the next testing level: 128 elements.

General Electric, the reactor builder, says that such problems are normal to any power plant startup, indeed that some were expected.

Another problem, cladding cracks, have not affected the schedule but may prove of broader significance; paradoxically, their discovery may result in an improved core.

The Fuel Cladding Tubes

The problem of defects in the zircaloy cladding tube walls posed no threat, GE said, to the testing program since it affected only 3% of the fuel and there were 10% spares on hand; but on the other hand it left a mystery in the air: what had caused the cracking.

Originally, the requirement of nondestructive testing on incoming zircaloy tubing for Dresden elements were a pressure test and an eddy-current test. A destructive burst test was given on samples of all lots of tubing. Ultrasonic testing was used only as a reference check.

"Subsequent investigation showed," GE told NUCLEONICS, "that a more sensitive check for internal defects in the tubing walls could be made with a modified eddy current procedure. This method was accordingly adopted for all remaining incoming material—about 30%. From the results of the new method on incoming tubes [which first revealed the tube-wall cracks penetrating half the tube thickness and reaching the inner but not the outer surface]. It was decided to recheck those segments which had been made up and assembled prior to the initiation of the new eddy current procedure.

"At the time modified procedure was incorporated in the fuel assembly production process [on July 7, 1959], 70% of the assemblies had been completed and shipped to Dresden. [These were all sent back to San Jose.] These are being replaced concurrently with the inspection program. By Dec. 23, the first core-load will have completed inspection," GE declared.

The 50 spare fuel elements will be checked by Jan. 6, GE said. The 3% of tubes found cracked will be junked, and replaced to bring the number of spares on hand at the plant back to 50, or 10%. The core-loading requires 488 fuel elements; together with the spares, they contain 44 miles of zircaloy tubing: 19,368 uranium-oxide-pellet-filled zircaloy tubes, 36 for each element.

The zircaloy for the tubing was cast into ingots and forged into extrusion billets by Mallory-Sharon Metals Co. at Niles, Ohio, and extruded and drawn to size by Bridgeport Brass Co. Both firms declined to comment on what might have caused the cracking. Reports were that extrusion rate, temperature, or the extrusion lubricant used, or any combination of those three, might have been the cause.

Nowhere was any doubt cast on the ability to fabricate sound zircaloy tubing; very similar tube has been in use in Shippingport without trouble. (PWR tubing got 100% ultrasonic plus 100% eddy current testing.) While it says it is using the best testing methods now available, GE frankly admits it is still not satisfied and is seeking better inspection equipment. It points out the 3% reject rate is meaningful only in terms of where the reject point is set. GE also noted that it had not been able to find any correlation between the tube defects and the failure of prototype Dresden elements under testing in the Vallecitos reactor, reported to ANS last June. No problem was foreseen for SENN, which will use Dresden-type elements.

The Control-Rod Drives

Failure of three control-rod drives led to modification of each of the 80 rod drives to prevent recurrence of the trouble: separation of the cruciform neutron-absorber plates from the drive pistons when shear pins broke. This was done at the site.

Designed to permit deliberate shearing for drive removal under certain conditions the pins broke from excess shock when hydraulic buffers, provided to prevent the control rods from slamming home too hard, failed. This in turn was traced to "badly cracked" graphite water-seals on the hydraulic buffer cylinders. The 38 seals that were cracked are presumed to have been damaged in shipment.

To eliminate the trouble, GE reset the shear pins to break 4 in. lower, and added a connector pin with 2 in. play so that even if the shear pin should break, the drive piston and the absorber section will not come apart. A timing device is also being installed on each drive to indicate poor buffer action and permit correction before any damage occurs.

STARTING NUCLEAR SIXTIES: WHO'S BUILDING THE CIVILIAN REACTORS*

1. Power

Reactor	Type	Output [Mw(e)]	Date of criticality
ALLIS-CHALMERS			
Elk River, Minn.	BWR	22½	Nov. '60
Sioux Falls, S. D. (Northern States)	BWR	66	1962
ATOMICS INTERNATIONAL			
Hallam, Neb.	SGR	75	1962
Piqua, Ohio	OMR	12½	July '61
site undecided, W. Germany (AKS)	OMR	150	1963
NS Esso Bolivar, W. Germany	OMR	71½	*mid-'63*
BABCOCK & WILCOX			
Indian Point, N. Y.	PWR	275	April '61
NS *Savannah*	PWR	16½	May '60
GENERAL ATOMIC			
Peach Bottom, Pa. (HTRDA)	GCR	30–40	Dec. '63
GENERAL ELECTRIC			
Vallecitos, Calif.	BWR	5	8/5/57
Dresden, Ill.	BWR	180	10/15/59
Humboldt Bay, Calif.	BWR	70	Mid-'62
Big Rock Point, Mich.	BWR	50	1962
Punta Fiume, Italy (SENN)	BWR	150	*End '62*
Kahl, W. Germany (RWE)	BWR	15	*End '60*
Tokai Mura, Japan (JAERI)	BWR	12½	1962
POWER REACTOR DEVELOPMENT CORP.			
Lagoona Beach, Mich. (Enrico Fermi)	FBR	100	end '60
WESTINGHOUSE			
Shippingport, Pa.	PWR	60–90	12/2/57
Rowe, Mass. (Yankee)	PWR	134	Oct. '60
Saxton, Pa.	PWR	5	Feb. '62
Parr Shoals, S. C. (Carolinas-Virginia)	PDR	17	June '62
Mol, Belgium (BR-3)	PWR	12	Sept. '60
site unannounced, Italy (SELNI)	PWR	165	Spring '63

2. Test and Research

Reactor	Type	Output [kw(th)]	Date of criticality
ALLIS-CHALMERS (successor to ACF Industries)			
Cambridge, Mass. (MIT)	D_2O	1,000	1958
Akron, Ohio (AFNETR)	D_2O	10,000	?
Ispra, Italy	D_2O	5,000	*1959*
Petten, Netherlands	*Tank*	20,000	*1960*
Studsvik, Sweden	*Tank*	30,000	*1960*
AMF ATOMICS			
Columbus, Ohio (Battelle)	Pool	2,000	1956
Plainsboro, N. J. (IRL)	"	5,000	1958
Buffalo Univ., N. Y.	"	1,000	1960
Mayagüez, Puerto Rico	"	1,000	1960
Sterling Forest, N. Y. (Union Carbide)	"	5,000	1961
Garching/Munich, West Germany	"	1,000	*1957*
Delft, Netherlands	"	10	*1957*
Hamilton, Ontario (McMaster Univ.)	"	1,000	*1959*
Seibersdorf/Vienna, Austria	"	5,000	*1960*
Athens, Greece	"	1,000	*1960*
Rishon le Zion/Rehovoth, Israel	"	1,000	*1960*
Saluggia/Turin, Italy (SORIN)	"	1,000	*1959*
Amirabad/Teheran, Iran	"	1,000	*1961*
Lisbon, Portugal	"	1,000	*1960*
Yesilkoy/Istanbul, Turkey	"	1,000	*1961*
Tokai Mura, Japan	D_2O	10,000	*1960*
ATOMICS INTERNATIONAL			
Chicago (Armour Research Fdn.)	Homogen.	100	1956
Washington, D. C. (Walter Reed)	"	50	1960
Risø, Denmark	"	2	*1957*
Frankfurt, Germany	"	50	*1958*
Tokai Mura, Japan	"	50	*1957*
West Berlin, Germany	"	50	*1958*
Milan, Italy	"	50	*1959*
BABCOCK & WILCOX			
Ann Arbor, Mich. (Michigan Univ.)	Pool	1,000	1957
Lynchburg, Va. (B&W Test Reactor)	"	10	1958
São Paulo, Brazil	"	5,000	*1957*
Hamburg, Germany	"	5,000	*1958*
CURTISS-WRIGHT			
Quehanna, Pa. (C-W Reactor)	Pool	4,000	1958
Rolla, Mo. (Missouri Univ.)	"	10	1960
Bangkok, Thailand	"	1,000	*1960*
FOSTER WHEELER			
Livermore, Calif.	Tank	1,000	1957
Risø, Denmark	"	5,000	*1959*
GENERAL ATOMIC			
Torrey Pines, Calif. (Hopkins Lab)	Triga	10	1958
Tucson, Ariz. (Arizona Univ.)	"	10	1958
Omaha, Neb. (Veterans' Hospital)	"	10	1959
Leopoldville, Belgian Congo	"	10	*1958*
Rome, Italy (CNRN)	"	100	*1960*
Seibersdorf/Vienna, Austria	"	30	*1960*
Seoul, Korea	"	100	*1960*
Dalat, Vietnam	"	100	*1960*
Belo Horizonte, Brazil	"	30	*1960*
Yokohama, Japan (Rikkyo Univ.)	"	100	*1960*
GENERAL ELECTRIC			
Vallecitos, Calif. (GETR)	Tank	20,000	1958
Pullman, Wash. (Wash. State)	Pool	100	1960
Palo Alto, Calif. (Stanford Univ.)	"	10	1960
Worcester, Mass. (W. Polytechnic)	"	1	1960
Moncloa/Madrid, Spain	"	3,000	*1958*
Hainchu, Taiwan, China	"	1,000	*1960*
Altos de Pipe/Caracas, Venezuela	"	3,000	*1960*
Quezon City, Philippines	"	1,000	*1960*
SINGLE SALES BY:			
Bendix Kansas Univ.	Tank	10	
Cook Elec. N. C. State College	Pool	10	1960
Daystrom Brookhaven Medical	Tank	3,000	1959
Convair Texas A&M Center	Pool	50	1961
Comb'n. Eng'g. Georgia Tech	D_2O	5,000	1961
Lockheed Ohio State	Pool	10	1960
NDA Tennessee Univ.	D_2O	10	1960
ACTED AS OWN CONTRACTOR:			
Westinghouse (for WTR)	Tank	20,000	1959
Virginia Univ.	Pool	1,000	1960
N. C. State College	Homogen.	0.5	1954
Penn. State Univ.	Pool	100	1955

* Reactors built by AEC or the national laboratories are not included in these tables. Foreign locations in italics.

N.B.—PWR = pressurized water reactor; BWR = boiling water; PDR = pressurized deuterium; SGR = sodium graphite; OMR = organic moderated; FBR = fast breeder; GCR = gas-cooled reactor.

Numec Opening $1-Million Lab; New Firm Grows Fast

Less than three years ago, three young scientists (photo) carried the atom into a Western Pennsylvania valley long suffering from anemia on the declining fortunes of its coal and steel economy. Long on nerve, imagination and talent but short on money and business experience, the trio set up shop in an abandoned steel plant under a rather fancy banner: Nuclear Materials and Equipment Corp., Apollo, Pa.

This month, just a few days past its third birthday, Numec will mark a milestone which assures itself and the Kiski Valley, 30 mi NE of Pittsburgh, an important role in the future of nuclear power—the opening of a $1-million laboratory dedicated primarily in its early years to the development of plutonium for power reactors.

The lab is there chiefly because AEC gave Numec a 42-month, $2.6-million contract to develop plutonium oxide through the entire fuel cycle (see box and NU, Apr. '59, 27). It was built, however, with private funds—$421,000 for the lab and $600,000 to equip it—contributed largely by local and state banking and investment interests who are betting on Numec's future.

NUMEC'S $1-million plutonium lab (top) as it neared completion last month. Three of the men responsible for it (below) are, from left: Zalman Shapiro, Numec president; Frederick Forscher, vice-president, metallurgy; and Leonard Pepkowitz, vice-president, chemistry.

Good Gamble?

An analysis of the Numec record under President Zalman Shapiro makes this look like an unusually good gamble. The company actually got into operation in Aug. 1957—nine months after its incorporation. In the 28 months since then, employment has shot up from a handful to 120 and the new lab will take it up to 175; billings have snowballed from $27,000 in the few active months of 1957 to $250,000 in 1958 and $800,000 this year; the venture has been profitable since early in 1958. Shapiro predicts billings of $2-million in 1960 and $12–16-million yearly by 1964–65. He adds:

"Beyond that, it's anyone's guess. It depends on the growth of the industry."

In this same 28-month period, Numec established itself as a worldwide supplier of fuel and other reactor materials; worked out, or initiated negotiations, for cooperative arrangements with Canadian, Italian, Belgian, Japanese, French and Swedish firms; entered the scrap-recovery and decontamination businesses (NU, Oct. '59, 128); went into production with the first three of several promising equipment items; laid the groundwork for materials-supply to the missile and other non-nuclear industries (rocket nozzle materials, for example), and inaugurated its PuO_2 program for AEC.

Problem Areas

The company has set this breathless pace despite several notable difficulties. First, there has always been a shortage of working capital and three financings have been necessary (the latest $1.1-million to be completed early in 1960). Second, Shapiro is a former Bettis scientist in the Naval Reactor Program and Numec has been shut out of this naval market since his departure from Bettis. Third, the nuclear fuel materials business is competitively fierce and the "ins" have understandably resisted this "newcomer." Finally, the company has had more than its share of a handicap generic with new firms—establishing its identity. ("Some people have had the impression that Numec was operating in the corner of a garage").

The truth is that Numec has been operating in a good-sized plant made available (in an extremely run-down condition) by an original (25%) stockholder, Apollo Steel. A con-

PuO_2 at Numec: Raw Material to Recycle

Under contract to AEC as a significant phase of the Fuel Cycle Development Program (NU, Apr. '59, 27), Numec is developing plutonium-oxide bearing fuel to be tested in existing reactors. The 42-month contract (now with 36 months to run) takes PuO_2 from the raw material stage, through fuel-bundle irradiation, and beyond to refabrication of irradiated fuel elements. A "companion" program for plutonium carbide is being carried out by Nuclear Development Corp. of America and Carborundum Co. Some highlights of the Numec program:

- **Preparation of PuO_2.** Work will be done on the preparation of PuO_2 alone and with such inert additives as the oxides of yttrium, calcium and zirconium and such active additives as thorium and uranium oxide. A key question here is whether to blend PuO_2 during the initial stages—by coprecipitation—or to attempt to reduce handling of PuO_2 by blending it in the final stage.
- **Fabrication of Shapes.** Work with pellets, plates, rods, etc. in essentially three categories—low, moderate and high enrichment.
- **Fuel Element Fabrication.** This phase of the program will give Numec a fuel-fabrication capability but the firm also has no long-range plans in this area. Principal objective is the test of a fuel assembly in an existing reactor.
- **Economics.** Develop cost estimates for the entire fuel cycle on a commercial basis.

tinuing remodeling and expansion program, however, will soon exhaust the Apollo space and force the company to look to the 58-acre site of its plutonium facility when further expansion is indicated. Meanwhile, Numec has recently completed a small facility for its new laundry and decontamination business (NU, Oct. 59, 128) near its converted steel plant. The Pu lab, 5 mi from company headquarters, will be used for several internal projects—production of neutron sources and U^{233}, for example—as well as the Pu work.

Technical Muscle

The firm is particularly proud of three recent technological developments growing out of its fuel-materials activities but kept pretty close to the rest for competitive reasons:

U Carbide. Avoiding the reduction-to-metal step, Numec has perfected a process for production of carbide directly from U-oxide and graphite. In addition, carbide has been cast into shapes of low porosity in diameters up to ¾ in.

Coated Spheres. High-density, uniform UO_2 spheres of diameters 40 to several hundred microns have been coated with a number of metals, including niobium, molybdenum, nickel, copper, chromium, aluminum and iron. Application techniques have included wet chemical methods, reduction in the vapor phase and electrodisposition. For fuel dispersions, the greater strength imparted to UO_2 particles by the coatings can prevent such effects as fragmentation and stringering during fuel fabrication. The coatings can also prevent reactions between fuel and matrix materials, as occurs with UO_2 and zircaloy, and reduce particle swelling under irradiation. Another potential use is in fluid-bed reactors; a chrome coating, for example, would inhibit abrasion of UO_2 particles moving around under various pressures from the coolant.

Scrap Recovery. Numec has just completed installation of new equipment for a precipitation scrap-recovery process which has a wide economic advantage over solvent extraction. It employs inorganic reagents and is applicable to uranium in combination with stainless steel, aluminum and zirconium. Major separation and decontamination is achieved via precipitation, with final purification probably via solvent extraction. Thus, the process may be useful for "hot," as well as "cold," fuel materials.

Advanced Gas Exchange Revives U. S.-U. K. Relations; Similar Agreement Expected on High-temperature Gas

The exchange of gas-cooled information between the U. S. and U. K. is undergoing a complete rejuvenation.

The recent agreement signed by AEC Chairman John A. McCone and by Lord Plowden, the chairman of the U. K. Atomic Energy Authority, to exchange information on advanced gas-cooled reactors has greatly expanded contact between the two countries and holds out the likelihood of even broader contact.

Information on development, design, construction and operating data is to be swapped in a three-project deal involving the U. K.'s Windscale and Hero (zero-power) reactors, on the one hand, and AEC's Oak Ridge Experimental Gas-cooled Reactor, on the other. On the horizon is another agreement covering the U. S.' High Temperature Gas-cooled Reactor, to be built at Peach Bottom, Pa., and the Dragon reactor sponsored by the U. K., Euratom and several member nations of the Organization for European Economic Cooperation.

Great expectations from U. S. work, based on the dynamic and heavily financed program that has developed in the U. S. within the last two years, were dangled as bait to lure the U. K. into the expanded exchange. AEC made the point also that it makes more sense to develop gas-cooled projects in close and continuing cooperation than to duplicate efforts—both economically and in terms of strengthening overall U. S.–U. K. scientific collaboration.

The advanced reactor exchange contains a clear stipulation that information received by either side may be made available to industry "for normal commercial use"; restricted documents, however, will be stamped "not for publication." Research and development data will be exchanged across-the-board but both sides will withhold some fuel-element manufacturing and reactor-design information.

Fuel Data. Included is data on composition of materials, cladding, overall design characteristics and similar information normally included in product specification. Excluded is data on specific temperatures, pressures, metallic bonding techniques and controls, which would normally be included in process, rather than product, specification.

Reactor Design. Similarly, reactor-design data exchanged will include arrangement drawings of final design, sufficiently explained to allow system design philosophy to be fully intelligible. Excluded are detailed design drawings, manufacturing specifications and detailed mathematical calculation supporting such drawings and specifications.

High-temperature Exchange

AEC Reactor Development Director Frank Pittman led a U. S. contingent to the U. K. last month to nail down an agreement on the exchange of high-temperature gas technology, thereby rounding out mutual contact on the gas concept. Since the arrangement involves Dragon, the European co-sponsors of this project are also in on the negotiations.

With only a few provisos—the most notable being a mutual agreement to bar publication for patent reasons—the negotiators were anticipating a complete exchange. Industry on both sides of the Atlantic will have access to the information but reports will carry "not for publication" or other suitable patent-protection language. AEC officials predicted early agreement on the exchange of written reports on high-temperature technology ("possibly a Christmas present") and—by mid-winter—agreement as well on the exchange of scientific teams.

Durham to Retire in Fall; Holifield in Line at JCAE

Rep. Carl T. Durham (D–N. C.), an original member of the Joint Committee on Atomic Energy and its chairman in 1957–58, will not be a candidate for reelection in 1960, he has decided.

Retirement of the veteran of 22 years' service in the House, who would have been chairman again in 1961–62, means that Chet Holifield of California, another original member, would be the next chairman if the Democrats maintain their majority in the House in the 1960 elections, with Melvin Price of Illinois in line behind him.

Should the Republicans elect a majority of the new House this fall, James E. Van Zandt of Pennsylvania would be the next JCAE chairman, with Craig Hosmer of California a second in line.

AEC Competition, Lack of Support Assailed by Industry

Four major industry associations have formally accused AEC of: 1. failure to assign sufficient AEC-financed work to industry; and 2. outright competition with industry at AEC-owned laboratory and production facilities. The protests were made at AEC's own invitation by the Atomic Industrial Forum and nuclear groups of the U. S. Chamber of Commerce, National Assn. of Manufacturers, and Manufacturing Chemists' Association.

NUCLEONICS obtained all comments but MCA's, which dealt primarily with alleged AEC competition at various stages of the nuclear fuel cycle. The industry critiques were requested by AEC in connection with two internal investigations, both initiated outside the Commission. For the first—a study of the role of AEC laboratories suggested by the Joint Committee on Atomic Energy (NU, Dec. '59, 19)—the Atomic Industrial Forum submitted to AEC 15 pages of criticisms and proposals adding up to a demand for more AEC-financed business for industry. AEC's report to JCAE was due Dec. 31.

For the second—an AEC report ordered by the Budget Bureau (see box and NU, Dec. '59, 27)—the USCC, NAM and MCA specified major and minor activities of AEC which industry feels are in direct competition with private enterprise. AEC's report to the Budget Bureau was due Dec. 31 but a several weeks' delay was considered likely because of AEC's extensive programs. It was reported that the Commission vetoed a staff proposal that AEC seek a blanket exemption from the Budget Bureau review on the ground that national security was involved in all AEC programs.

AIF Critique

The Forum's report on AEC laboratories was written by Carroll Wilson, former AEC general manager, and submitted to AEC Oct. 22 after review by Forum members who had attended a meeting on the lab issue in September. It made these major points.

1. Development and engineering of reactor systems—whether AEC-financed or not—must be done by industrial firms. "Power reactors and systems are going to be made and sold by industrial manufacturers and not by AEC laboratories."

2. There is no justification for AEC labs pursuing a reactor concept beyond the experiment stage "and even here substantial industrial participation would be valuable."

3. At least "one-half of AEC research and development expenditures on reactor technology" should be spent with industry; moreover, a formal program for achieving and maintaining this objective should be established.

4. The focus of AEC lab interest should be basic research where the ultimate outcome is not clearly defined "and where the risk is too high to warrant industrial interest." Ratios of basic to applied research at three national labs are, respectively, Oak Ridge, 75% applied, 25% basic; Argonne, 50-50; and Brookhaven, 25-75.

5. New construction and personnel buildup at the labs have proceeded "at a sharply rising trend" in recent years.

Chamber of Commerce

The USCC report was drawn up by an atomic energy subcommittee on government competition with industry; it went to AEC Chairman John McCone on Dec. 7. Some highlights:

1. Areas of AEC competition with industry in fuel-element fabrication include: Oak Ridge National Laboratory (makes the elements for most of its reactors); nuclear rocket program; the projected process-heat reactor sponsored jointly with the Interior dept.; Savannah River (some production elements and all elements for the Heavy Water Components Test Reactor), and Hanford (fabricating all of its elements).

2. Major research and development projects that should have been assigned to industry include: the Natural Circulation Submarine Reactor assigned to Knolls Atomic Power Laboratory; Argonne's Title 1 design of the process-heat reactor and its development of the Army Low Power Reactor; the Lawrence Radiation Laboratory's design, test and fabrication of nuclear ramjet engines; all experimental work at Los Alamos on thermionic cells for direct conversion of fission energy; and the radiation-instrument development done by "each of the major government projects" in the nuclear field.

3. Industry is capable of producing several radioisotopes marketed by AEC, including cobalt-60, iodine-131, carbon-14, sulfur-35 and phosphorus-32.

4. AEC is allegedly failing to give preference to private irradiation facilities over the Materials Testing Reactor (MTR) and the Engineering Test Reactor (ETR) in Idaho. "Underloaded commercial facilities exist, whereas it is our impression that the government-owned facilities are heavily loaded. AEC's practice of offering space in the . . . MTR and ETR should be limited to only those specific cases where private facilities are unavailable."

NAM on Fuel Materials

The NAM report was particularly outspoken on fuels competition, although it also pointed to many of the same programs as USCC. On the fuel cycle, NAM's Atomic Energy Committee Chairman James Fairman of Consolidated Edison had this to say in a Dec. 4 letter to McCone:

"There is a substantial existing private industry to process uranium from the mine to fabricated reactor cores with the exception of the uranium-235 enrichment process. Everywhere that the government operates in its own facilities in this area, with the noted exception, there is direct competition with industry."

NAM examples in support of this comment: enriched-U materials for all U alloys or compounds for the Nuclear Navy (a huge market), for the Experimental Gas-cooled Reactor, for ETR and MTR, and for the new production reactor at Hanford.

Minimizing Government Competition

The Budget Bureau, in its Bulletin 60-2 to all government agencies (Sept. 21), reiterated the Administration's policy of non-competition with industry anywhere industry can do the job. Three conditional exceptions were noted:

- **National security.** Although government must perform some defense-type activities, commercial contractors should be given as much of this business as possible under proper safeguards.
- **Cost.** Exception applies only if commercial costs are "substantial and disproportionately large."
- **Clear unfeasibility.** Applies if the product or service is an integral function of the agency, if there is no commercial supplier, or if it is administratively impractical to contract for.

Britain: Some Advances, Some Setbacks Reported

A number of significant atomic stories were coming from Britain last month. The highlights:

AGR: On Schedule

Site work on the 28-Mw(e) pilot Advanced Gas Reactor at Windscale (*see photo*), due for early 1961 criticality, is on schedule, despite some laboratory problems in development of the beryllium cladding for its uranium oxide fuel (*see below*). AGR will be graphite moderated, with CO_2 coolant at 1000° F and 270 psi, and fuel surface temperatures reaching 1115° F. A 21-ft dia, 60-ft high double-walled domed cylindrical pressure vessel and four heat exchangers each with its own biological shield are housed in an inverted-pear-shaped containment vessel with a 150-ft dia hemispherical dome. AEA is withholding information on a number of novel engineering features of the AGR design notwithstanding its industrial character; a spokesman says this is solely because "The British taxpayer deserves some rebate for his outlay."

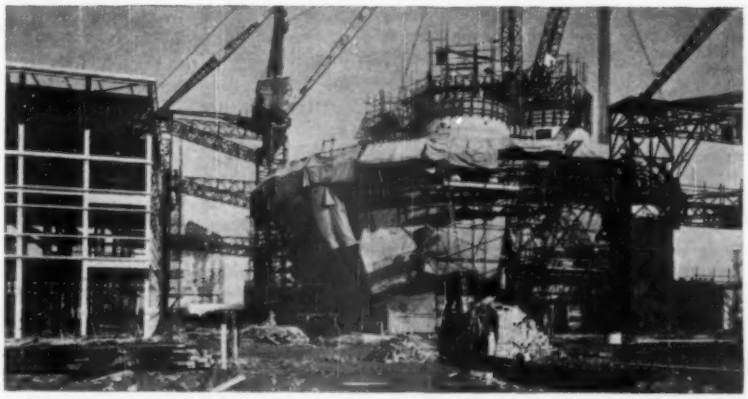
CLADDING BATTLE: Beryllium vs Stainless Steel

A dramatic struggle is being fought in Britain's metals laboratories between beryllium and stainless steel (and by both against time) to be ready as cladding material for the pilot Advanced Gas-cooled Reactor (AGR), now rising at Windscale. With each metal threatened by a different weakness (NU, Dec. '59, 26), the race may well go down to the wire.

A recent visitor to the AEA-operated fuel fabrication plant at Springfields (still Britain's only one) reported great activity on fabrication of beryllium-clad elements for AGR. However the likeliest solution seen for the dilemma at Windscale is a 50-50 or 60-40 compromise using both metals, in different parts of the core.

The consensus appears to favor the ultimate establishment of beryllium.

Meanwhile stainless is seen as a useful stop-gap, even though due to the degradation of its fatigue characteristics under operating conditions it may not realize a five-year life at 10,000 Mwd/ton as expected. And—whatever the decision regarding AGR's cladding—both the Nuclear Power Plant Co. and the General Electric Co. group are already basing their design work for the commercial-scale, AGR-type stations that they will bid to the Central Electricity Generating Board on stainless-steel cladding.



ADVANCE GAS REACTOR rises at Windscale. Note conical containment vessel

CHAPEL CROSS: Third Unit on Line

The third 42 Mw(e) gross, 35 net, Chapel Cross reactor reached full power Dec. 2, roughly on schedule. The fourth unit (eighth and last of the original Calder Hall design) was to go critical late in December, reach full power in March.

A-SHIP: No Action Yet

All the British reactor systems proposed for development for a first U. K. nuclear merchant ship (NU, June '59, 25; July, 76) are believed to have been rejected. Only the three U. S.-developed types—pressurized water, boiling water and organic moderated—are believed to have been approved as suitable for immediate development. Negotiations are proceeding with a British oil company with a view to building a 40–60,000-ton tanker; the possibility of the industry forming a consortium to handle development of the project with government backing is being discussed. Cost of the reactor, about $9-million, would be borne by the government.

Later, the government invited bids on boiling-water and organic-moderated reactors to drive a 65,000-ton tanker. Proposals are expected in a few months, and only then will the government decide whether or not to order the vessel.

LABOR TROUBLE: Three Stations Delayed

Negotiations began early last month for resumption of site fabrication work at the Hunterston nuclear power station between union officials and Motherwell Bridge & Engineering Co. Ltd., subcontractor for pressure vessels and heat exchangers. Only limited civil engineering work has been able to go on since work was suspended Sept. 25 after a long history of labor stoppages occurring at regular two-week intervals since site work commenced (NU, Nov. '59, 29). Hunterston is already 12–18 months behind schedule. Moreover Bradwell and Berkeley station are also six months behind, for the same reason. Wage claims by welders and radiographers have been one of the most persistent causes of trouble; pay rates have already soared to $180/wk, an all-time high for British craftsmen. Yet at some sites the men work for one hour and choose to rest for one hour. Fabrication of 3-in. thick plate demands special welding skills.

ZENITH: Goes Critical

Zenith, first unit in the British HTGR program to develop a High-Temperature Gas-cooled Reactor, went critical on Dec. 19 at the new reactor center at Winfrith Heath. Zenith, although a zero-energy unit, will operate at high temperature (1475° F); it is predecessor to the 10-Mw Dragon, to be built at Winfrith as a European Nuclear Energy Agency (OEEC) project. Development of the HTGR graphite-clad-fuel series is scheduled to reach commercial scale after the AGR series.

Reactor News

NONNUCLEAR TESTING OF FERMI PROGRESSES

With erection of the major reactor components of the Enrico Fermi fast breeder completed, their testing—with electric heating elements (and later an external oil-fired heater)—is entering the fifth month of a year-long program. To date the mechanical handling mechanisms have been operated satisfactorily at room temperature and up to refueling temperatures of 525° F. Some early difficulties were encountered with conventional hardware items such as rubber gasket seals, but these have been corrected, at testing temperature. Next steps will be: operation of individual reactor mechanisms in argon, then in sodium; integrated operation of all control and handling mechanisms at temperature; filling and draining with sodium to establish operating procedures and check auxiliary systems; run reactor sodium system and control mechanisms at all conditions of flow and temperature. Although there has been some slippage in the original schedule, it is still seen possible to complete the nonnuclear testing by Nov. 1, 1960, and to go critical by Dec. 31.

HERCULES PATENTS NEW CHEMOREACTOR

A chemical processing reactor in which the process fluid is circulated through the primary together with the fuel has been patented by Hercules Powder Co. The intimate contact between enriched UO_2 dust fuel and raw material in the core permits over half the fission fragment energy to be used in breaking up the molecules of the raw-material gas; the free radicals thus formed recombine in new ways to form the desired products. Hercules has run 18 months of in-pile tests at Battelle irradiating methanol and achieving a 65% yield of ethylene glycol, figures that a reactor built for $150–200/kw(th) would produce glycol at competitive prices. Other organic compounds could be made. Hercules has asked AEC for support to develop the system as a nitrogen fixation plant, on a 13-years-to-prototype schedule.

HIGH FLUX REACTOR STARTING AT BNL

Contract negotiations at Brookhaven National Laboratory are underway for an architect-engineer for the $10-million High Flux Beam Reactor to be built southeast of the BNL Research Reactor for 1963 completion, and preliminary design work has begun. The heavy-water-moderated and -cooled unit, producing 20 Mw(th) or more, will use MTR-type fuel elements and will have an undermoderated core since it is intended primarily for external beam research. Peak thermal flux will occur in the D_2O reflector a few inches from the core tank; expected fluxes are 1.5×10^{14} peak (at 40 Mw) total thermal; 6×10^{14} peak (at 40 Mw) total epithermal.

AEROJET-GENERAL DROPS TEST REACTOR

Aerojet-General Nucleonics has withdrawn its application to AEC for a license to build and operate its planned 10-Mw testing reactor at San Ramon, Calif.

SECOND A-CARRIER SUNK; POLARIS GAINS

The Navy's second nuclear carrier, voted by Congress instead of the conventional carrier asked by the Administration, has been torpedoed by the latter at a budget conference at the Augusta (Ga.) National Golf Club in mid-November. "We very much prefer to have a new conventional carrier," then-Secretary of Defense Neil McElroy explained. Earlier last year the Senate had insisted that if any carrier were built, it should be the best and most modern technically possible: i.e., nuclear-powered; Congress voted funds for advance procurement of reactor components for a second A-carrier (NU, Sept. '59, 73). This is the second year running that a sistership to *Enterprise* has been blocked. . . . *George Washington*, tenth A-sub to go to sea and first of the Polaris-firing ones, passed its first trials with flying colors. Its reactor was brought to full power within five hours after trials began, maintaining the nuclear navy's record of having each of the ten nuclear subs operating at full power on its first day at sea. *GW* met all specifications for speed, submersion and controllability, will now give the Polaris missile its final development-to-operability tests. . . . Newport News Shipbuilding & Drydock Co. got a $26.7-million contract to build an 18,300-ton submarine tender to service Polaris-firing A-subs (NU, Sept. '59, 81). . . . Newport News launched its first A-sub, *Robert E. Lee*, fourth of the Polaris series, Dec. 18. . . . *Scorpion*, *Skipjack's* first sistership, was launched Dec. 11 at Electric Boat. . . . Carrier Corp. has received a $3-million contract to produce quieter heat-operated cooling machines for A-subs beginning with *Thresher*, first of the faster, quieter *Skipjack* class.

NTP CONSTRUCTION TO START SOON

Field construction of the Nuclear Test Plant is to start at the National Reactor Testing Station, Idaho, this spring. C. F. Braun & Co., Alhambra, Calif., has been named architect-engineer for the $5-million facility, which Combustion Engineering is designing (NU, Oct. '59, 23). NTP will be able to test entire cores up to 60 Mw(th) in pressurized or boiling water.

THREE VALVE RESEARCH JOBS FOR CRANE

Crane Co. has three research contracts, totalling $250,000, for as many kinds of primary coolant valves. Biggest contract ($172,000) is from Electric Boat division, General Dynamics, for a high-temperature gas stop-valve for the MGCR (Maritime Gas Cooled Reactor) in which coolant will be helium at 1500° F, 1000 psi. An AEC contract—part of the Commission's sodium components development program—calls for design of a throttling gate valve to handle molten sodium at over 1200° F; a new valve concept is being proposed.

DAVISON, 5 UTILITIES IN REPROCESS STUDY

The first big break in private-industry entry into chemical reprocessing of spent fuel came last month, and Davison Chemical division, W. R. Grace & Co., seemed to have gotten a huge jump on the field. Davison corraled the builders of Indian Point, Dresden, Fermi, Sioux Falls and Yankee reactors for a feasibility study on a private reprocessing plant. They set up Industrial Reprocessing Group to explore technical and economic aspects of designing, building and operating a solvent-extraction unit using a Purex- or Redox-type process. Original members: Commonwealth Edison, Consolidated Edison, Detroit Edison, Northern States Power Co., Yankee Atomic Electric Co., and Davison; others may join later. IRG is seeking access to AEC data for the six-month study, for which the participants are putting up $250,000 in equal shares. The utilities feel so strongly about having their spent fuel reprocessed in a privately-owned facility that they are willing to accept costs up to 20% higher if necessary to that end. T. C. Runyon, in charge of Davison's Erwin plant and an original patenter of Purex, will head the study.

World News

Germany Clears AKS Reactor . . .

The Bonn government has finally agreed to grant an operating loss subsidy to the AKS group (up to 50% of losses with a ceiling of $24-million and 15 years), thus assuring construction of West Germany's first full-scale power reactor. The 150-Mw(e) organic-moderated unit will be supplied by Interatom, a joint subsidiary of Atomics International and Demag; Brown, Boveri of Mannheim will build the conventional end. The reactor, to be completed in 1963, will cost $57–65-million, of which $8.3-million will come from Bonn and $20.2-million from the U. S.-Euratom credit fund.

. . . and Moves for OMR-Propelled Tanker

Placement of a construction order with Interatom for another organic-moderated reactor, a 10,000 hp unit for ship propulsion, is "pretty well settled," NUCLEONICS' Bonn bureau reports. It will be bought by the Hamburg Association for Nuclear Energy Utilization in Shipbuilding and Shipping, which is also buying a tanker in which to install it—the 16,000-ton *Esso Bolivar*, built in 1937, owned by Esso Tankschiff Reederei. Cost of the conversion is placed at $5–7.14-million, including cost of the reactor. Construction is to start in summer 1961, for completion in summer 1963. Three other German shipyards are considering plans for nuclear-propelled ships: Howaldtswerke, Hamburg, a Siemens pressurized-water reactor; Deutsche Werft, Hamburg, an AEC boiling-water unit; and the Krupp-owned AG Weser yard, Bremen, a Krupp–Brown, Boveri high-temperature gas-cooled machine.

German Atomic Law Passed

The long-awaited Federal German law on application of atomic energy for peaceful uses has been passed by the Bundestag, finally ending legal uncertainties hanging over the program. A previous version was unexpectedly torpedoed in the Bundestag 2½ years ago (NU, July '57, 19). The law leaves nuclear projects in the hands of private industry, but as a concession to the Social Democrats who wanted government control, the government is given some say on granting reactor construction permission and use of fuel. Up to $120-million in government funds in excess of insurance cover is provided for third-party liability.

Heroic Troubleshooting at France's G-2

When the prestressed concrete pressure vessel of the G–2 power reactor at Marcoule was heating up unevenly for unexplained reasons a few weeks ago, a French engineer crawled into the core after the reactor was shut down and the CO_2 coolant exhausted, to try to find the trouble. Clad in a heavy protective suit, with a breathing device and a Geiger counter, the engineer crept through the coolant tubes into 122° F heat to check the cooling circuits. He apparently suffered no ill effects, and was followed by other technicians in relays; the reactor was put back in operation. It is now running, but France's CEA has not said how long it was down. Nor has it identified the engineer.

Parley Sees A-Ship Profit by 1970

Nuclear powered merchant ships will be economically competitive in about 10 years, it was generally agreed at a 3-day international conference on atomic ship propulsion in Hamburg last month. German calculations are that capital costs today are twice as high, operating costs 50% higher than conventional. The meeting showed that German scientists, barred from atomic work from 1945 to 1955, have caught up with international developments at least in this field. . . . Meanwhile the International Atomic Energy Agency suddenly postponed for a year a meeting on nuclear ship propulsion a week before its scheduled start, saying it was too early to hold it.

Finns Ask IAEA for U-235

The International Atomic Energy Agency has received its first request for enriched uranium. Finland has asked for 2.6 kgs 20%-enriched uranium by this fall for a Triga to be set up near Helsinki, and 3 kg 10%-enriched needed by mid-1961 for a critical assembly; also for aid in fabricating the material into fuel elements. This first call on the 5,140 kg U^{235} made available to IAEA by the Big Three is seen by Agency Director General Sterling Cole as "a very encouraging step" toward fulfilling IAEA's original intended role as an international broker for nuclear fuel (only previous IAEA sale was of Canadian natural U to Japan). Austria is also expected to ask for U^{235} for its Triga research unit.

Canadians to Start Second A-Research Center

Spilling out from Chalk River, Ont., Canada's national nuclear program will occupy a second center (NU, Nov. '59, 29). Location chosen for the $2-million center is on the east bank of the Winnipeg River 4 mi SE of Lac du Bonnet. A new residential community will also be built, like Deep River, Ont., housing the Chalk River workers. . . . Canada's first nuclear power plant, the $32-million 20-Mw(e) Nuclear Power Demonstration reactor (NU, Sept. '59, 30), has reached the construction halfway mark last month as installation of components began. The plant is to go on the line by mid-1961.

IAEA Discusses Waste Disposal

308 experts from 32 countries attended the first international conference on radioactive waste disposal, held in Monaco by IAEA jointly with Unesco. One achievement of the meeting, said G. W. C. Tait, IAEA's director of health, safety and waste disposal, was in showing that many of the differences of opinion about approaches to waste disposal were founded less in real difference of principle or philosophy than in differences of definition—and a number of important clarifications were reached at the conference.

AI in New European Subsidiary

Atomics International is reported to be setting up a second European subsidiary jointly, this time, with two French firms active in atomic energy: the shipyard Chantiers de la Loire and the electrical equipment maker Société Alsacienne de Constructions Mechaniques (SACM). The new firm may be called Dynatom. AI is already half-owner of Interatom with Demag of Germany, and has cooperative arrangements with English Electric Ltd. and ASEA of Sweden.

Belgian Power Reactor Core Tested

The core for BR-3, Belgium 11.5-Mw(e) first power reactor, has been successfully tested critically at the Westinghouse Reactor Evaluation Center, prior to shipment to Belgium.

France May Lend Tunisia a Reactor

France may lend Tunisia a small demonstration reactor, Peg, for training purposes. Peg is a 100-milliwatt pool fueled with 7 lb enriched uranium.

News in Brief

Administration Still Undecided on Future of ANP

Government officials disclosed last month that the Administration has not yet decided how it will apportion funds over the next few years to the two competing approaches to nuclear aircraft—General Electric's direct cycle program and the indirect cycle of Pratt & Whitney. The all-important budget factor has not been dealt with despite the public announcement of last summer (NU, Sept. '59, 28) that: 1. An early direct-cycle plane would not be built; and 2. The indirect-cycle program would be stepped up. The administration is understood to have given itself a March deadline for laying out a new Aircraft Nuclear Program assigning respective measures of support for each approach. In fiscal '59, $50-million in AEC development funds went to the GE approach, $16-million for the indirect cycle.

HTRE-3: First published photo of experimental ANP unit

Savannah Passes Two More Reviews

What is surely one of the most reviewed projects in the history of commercial nuclear power—NS *Savannah*—has "passed" its second and third examinations within the last nine months and is expected to emerge from reviews No. 4 and 5, with only minor modifications, before the winter is out. Review No. 1 was that of the Naval Reactors branch at the request of AEC Chairman John A. McCone (NU, Oct. '59, 18); No. 2 was conducted by AEC's General Advisory Committee and was reportedly "very favorable" to the ship; No. 3 was conducted by an ad hoc committee organized by Frank Pittman, director of the Reactor Development div., and was also favorable to the project; No. 4, Pittman's report to the Commission, is scheduled to be submitted this month; and No. 5, the Commission's review, will wrap it up.

The comment of *Savannah* officials last month: "All these reviews have been most helpful and we've had some good ideas." Loading of the ship's fuel is expected to start in late spring; any changes in her design reflecting the comprehensive series of reviews are expected to be minor.

Industry to Get Crack at Advanced Test Reactor

AEC officials said last month they expect in the near future to invite industrial firms to bid on construction of an advanced, high-flux test reactor to meet the needs of AEC programs—primarily the naval reactors program. Formal invitation for industrial proposals has been delayed while AEC users review their requirements and a conceptual reactor designed prepared by Phillips Petroleum (NU, Dec. '59, 20). Some staff officials regard it as unlikely that industry will get the job—because the chief customer is the Naval Reactors branch and because AEC would have to provide most of the construction and operating funds. However, there is unprecedented pressure on AEC to undertake no program which industry is willing to undertake—and several firms are anxious to build this plant.

Government Easing Access to A-Rocket Data

Administration officials said last month they were modifying the ground rules for access to information on the nuclear rocket program (Project Rover) to permit access by some firms now barred. Several firms have complained that they were shut out of the program because they could not demonstrate a clear "need to know" and could not submit sensible proposals without information on where the program stood. The "need to know" criterion, government officials said, has been supplemented by a second—qualification of a firm to make use of the data.

Staff Named by Federal Radiation Council

The Federal Radiation Council, new policy-making body for the government on radiation matters (NU, Sept. '59, 21), has set up its working staff from among the five member agencies. Chairman is Robert Huntoon of the National Bureau of Standards. Others are: David Price and Edwin Laug (alternate), Health, Education and Welfare dept.; Nathan Woodruff, AEC; Carl Tessmer, Defense dept.; and Richard Schwartz, Labor dept. Also working with the group is Donald Chadwick, secretary to the Council, who is on loan from the U. S. Public Health Service. Council Chairman Arthur Flemming, secretary of Health, Education and Welfare, has been asked to report to the Joint Committee on Atomic Energy by Feb. 1 on the radiation-standards posture of the U. S. In April, JCAE expects to hold public hearings on radiation safety, including the role of FRC and HEW in establishing standards.

AEC Creates Aerospace Nuclear Safety Board

The ever-present issue of nuclear safety has penetrated to outer space. AEC has established a 12-man Aerospace Nuclear Safety Board to: 1. study the possible effects of nuclear space devices on human health; 2. establish a procedure for keeping track of nuclear devices in space which pose a threat to earth and elsewhere; 3. recommend safe practices; and 4. recommend procedures for requesting the use of nuclear energy in vehicles and satellites sponsored by the U. S.

News Notes: Contracts, Honors, a New Facility

High Voltage Engineering Corp. has sold three Tandem Van de Graaff accelerators to AEC (each 12-Mev). At a cost of about $1.1-million each, the machines will go to Argonne and Oak Ridge National Laboratories and Rice Institute. . . . **Spencer Chemical** has won two substantial contracts for uranium dioxide: 6,000 lb natural UO_2 for the Plutonium Recycle Test Reactor at Hanford; and 14,000 lb 4.3% enriched UO_2 for half the second core of NS *Savannah*. . . . **Fairbanks Whitney Corp.** plans establishment of a thermoelectric power research center in Albuquerque, N. M. . . . AEC has established the **Ernest Orlando Lawrence Memorial Award** in honor of the late director of California Radiation Laboratory, Berkeley and Livermore. A medal, citation and up to $25,000 will be awarded for recent contributions to atomic energy in any area of science, particularly by young scientists. . . . **Eugene Wigner** of Princeton has been appointed to AEC's General Advisory Committee, succeeding Edward Teller for a term expiring Aug. 1, 1962.

Rockefeller Endorses Ten-Point A-Plan for N. Y.

A ten-point atomic program for New York State has been proposed to the legislature by Governor Rockefeller. Based on a 12-point program drawn up by his Director of Atomic Development, Oliver Townsend, the Governor's recommendations failed to call for construction of an economically-competitive full-scale nuclear power plant or of a prototype "leading directly toward construction" of such a plant.

This first objective of the Townsend plan was not embodied in the Governor's legislative proposals because, Rockefeller said, "the question of atomic power generation should appropriately await the imminent report of the Governor's Committee on Power Resources." The other proposal not taken up had called for establishment of additional nuclear training facilities; this is to be considered in the light of work now underway for a Nuclear Research Center at Buffalo U.

The Governor's proposed legislation called for the state to: acquire sites for 1. concentrating and storing radioactive wastes, 2. a high-flux test reactor, and 3. a port facility to handle used fuel from nuclear ships or brought in from land power stations; 4. execute an agreement with AEC providing for assumption by the state of regulatory authority over radioisotopes and other nuclear materials; and 5. establishment of training programs for handling of accidents involving radiation, and preparation of a roster of personnel and accident equipment.

Five other points on which legislation is not required but which the Office of Atomic Development will carry forward, are: 6. encouragement of private industry to build a process heat reactor in the state; 7. construction of a chemical reprocessing plant; 8. establishment of a shipyard to build nuclear-propelled ships; 9. expansion of fuel fabrication including entry into fabrication of fuel specifically for ship propulsion; 10. expansion of industrial use of radioisotopes and of research to find new uses for them.

Radiation News

Australians to Increase Size of Irradiator

Less than two months after the world's largest commercial isotope irradiator (150,000 curies) went into operation near Melbourne, Australia, its owners have decided to increase its capacity. The facility was ordered from the UK for fumigation of raw goat hair (NU, Aug, '59, 25) but the demand for space from pharmaceutical and other manufacturers has converted it into an all-purpose facility. Capacity will be raised to 500,000 curies as fast as the U. K. can deliver the cobalt—one-third for goat-hair, the rest for pharmaceuticals, etc.

Food Irradiation: Three Comeback Developments

The nation's food-irradiation program, buffeted about by various ill winds over the last few months (NU, Dec. '59, 17), began something of a comeback last month with these developments:

1. The Army Quartermaster Corps put the final touches to a revised program it is recommending to Richard Morse, Army research and development chief who ordered cancellation of the proposed Ionizing Radiation Center, Lathrop, Calif. Major elements of the suggested program are a 1-million-curie cobalt-60 irradiator and a narrowing down of the number of foods to be emphasized for radiation processing. The Co^{60} irradiator would be a relatively simple facility with comparatively little of the food-processing equipment proposed earlier.

2. The Administration's 9-agency Interdepartmental Committee on Radiation Preservation of Food, at a meeting Nov. 24, set up a committee to recommend a food-irradiation program attuned to commercial applications and supplementing the military program. The committee, proposed by and to be chaired by Paul Aebersold, AEC isotope development director, is to report back by Feb. 1. It will give primary emphasis to low-dose pasteurization of fish, fruits, meats, etc., and the feasibility of taking a limited number of these food items to commercial status. The ad hoc group would also be expected to estimate the cost of such a program in fiscal 1961 and succeeding years, including construction of one or more radioisotope irradiators.

3. The Joint Committee on Atomic Energy scheduled an inquiry into the Army's decision to drop the Lathrop center. Public hearings were tentatively set for late January or early February.

Bureau of Mines Plans Big Cobalt Source

Construction of a 100,000-curie cobalt-60 irradiator, for the study of the gamma processing of coal, petroleum and certain metals, is under consideration by the Bureau of Mines. The Bureau has already contacted all firms who bid on the 2.2-megacurie Co^{60} irradiator for the Army's food program (NU, July '58, 27) for preliminary indications of what they might propose. A formal invitation to bid, it is understood, will go out after the Bureau reaches agreement with AEC on the supply of Co^{60}. All of the Bureau's 20 research stations are possible sites, but the Schuylkill Haven, Pa., station is reported to be the favored location. Bureau spokesmen indicated they were quite excited over research findings that led to the decision to build the facility.

RAI Sells Cesium Irradiator to Ireland

The Government of Ireland has given Radiation Applications, Inc., a design-construction contract for a 700-curie cesium-137 irradiator. The facility will be installed at the Univ. of Dublin this spring for research in botany and genetics.

AEC to Seek $4–5-million for Isotope Program

The Budget Bureau has cleared for submission to Congress an AEC request for $4–5-million in fiscal-1961 funds for the Isotope Development Program. The program has $4-million for the current fiscal year, ending June 30. The '61 request will go to Congress this month as part of AEC's total budget, which is understood to be at the same $2.7-billion level as this year's budget. AEC had sought an additional $200-million from the Budget Bureau, it was reported, but was turned down.

To Build Strontium-Powered Weather Station

An isotopic-powered automatic weather station—using 20,000 curies strontium-90 as the source of heat for conversion to electricity—will be built this year at the Frederick, Md., station of the U. S. Weather Bureau. Sponsors are the Bureau and AEC. The facility is a prototype for remote stations (Arctic, etc.) capable of producing 5 watts for trickle-charging of batteries and higher power for multi-second periods.

ALSO OF NOTE . . .

New Argonne reactors begun last month were Juggernaut, a 250-kw, low-flux special-purpose research reactor, light-water-moderated and fully-enriched U fueled, to be completed late this year; and Zero Power Reactors ZPR-6 and ZPR-9, for mid-'61 completion. All three are for fast-reactor research.

Five minor radiation incidents occurred in a month at Oak Ridge, Los Alamos and Idaho's reactor testing station. Three occurred at Oak Ridge: a stack "burped" some ruthenium-106 after a fan repair, some low-level waste from the chemical-reprocessing plant leaked into a controlled stream, and a small cleaning-fluid explosion scattered some active material. At Idaho a low-level criticality incident, when process solutions escaped into a waste tank, overexposed two persons, but they didn't need to be hospitalized.

Italy is starting a thorium-U^{233} program, wants to build a pilot processing plant and remote fuel-element fabrication plant, has asked the aid of Allis-Chalmers (which is using thorium at Elk River), and has sounded out AEC on buying spent Elk River fuel elements for practice material.

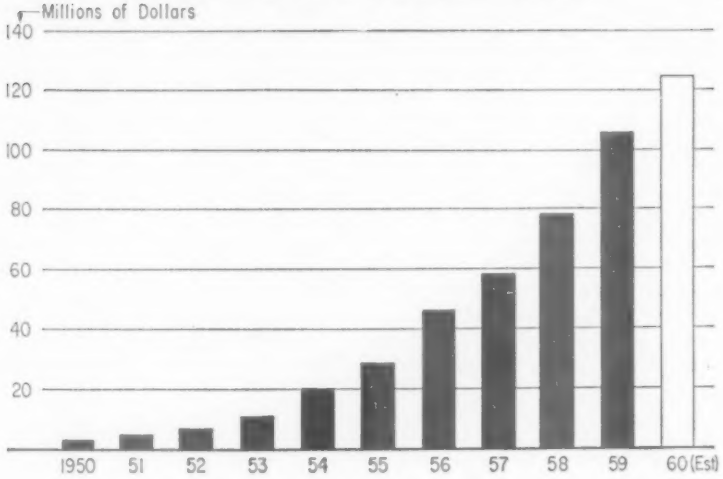
Elk River's construction permit fell afoul of a Federal-State hassle when AEC said it could not grant it on the terms demanded by Minnesota's Gov. Orville Freeman, who wants "opportunity to review independently" the plants radiation hazards standards. Minnesota is the first (and still only) state to seek control over nuclear facilities (NU, Feb. '59, 26). As an AEC-owned reactor, Elk River does not require a construction permit, is due for completion this November.

Olin Matheson has obtained the contract to fabricate the fuel for the D1G prototype and two D2G seagoing destroyer reactors.

Japan and Britain's General Electric Co. finally signed a contract for an improved, earthquake-proof 150-Mw(e) Calder-type reactor (NU, April '59, 24; Nov., 28).

Aerojet-General Corp. set up a new division, Aetron, to integrate the company's capabilities in architectural engineering and electronics. The division, with about 800 staff (400 professional), will bid on nuclear power plant construction jobs in association with Aerojet-General Nucleonics or other reactor designers; it bid with Atomics International on OMRE-2.

NUCLEONICS Statistics of the Quarter



AEC Research Development Spending, Civilian-Power Reactors

	Latest month	Month ago	Year ago
Nuclear Contracts *—			
Contracts awarded for federal projects (10^3)	56,107	7,869	4,916
Proposed construction, privately-owned (10^3)	0	0	23,000
Contracts awarded, private work (10^3)	644	0	0
Backlog of private projects (10^3)	285,549	285,549	277
Isotope Use †—			
Applications for isotope use	562	689	652
Cumulative total of isotope users	5,354	5,267	4,323
ORNL shipments (curies)	23,926	27,712	14,300
Public and private export shipments	339	260	339
Employment †—			
AEC employment	6,678	6,711	6,911
Construction and design contractors' employment	9,502	9,656	11,659
Total operating contractors employment	103,881	106,029	103,389
Production workers	51,212	51,883	51,153
Research and development employees	47,782	49,514	45,986
Miscellaneous workers	4,887	4,632	6,250

U. S.-built Reactors ‡—	Operating	Building	Contracted
Power, domestic	1	8	7
Power, for export	0	3	2
Power experiments and pilot plants	6	6	0
Military and naval	14	40	5
Research and test, domestic	63	18	56
Research and test, for export	16	19	3
Total	100	94	73
Foreign-built Reactors ‡—			
Power, domestic	16	22	17
Power, for export	0	2	1
Research and test, domestic	37	8	11
Research and test, for export	8	6	0
Total	61	38	29

* From *Construction Daily*, a McGraw-Hill periodical † From AEC ‡ NUCLEONICS figures

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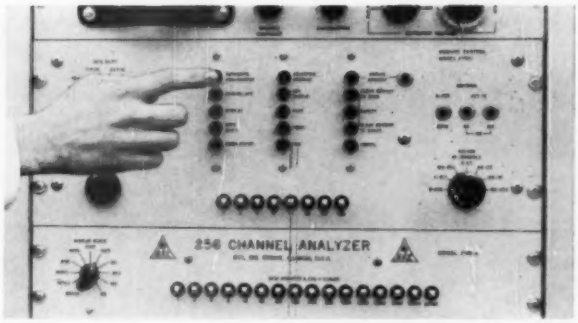

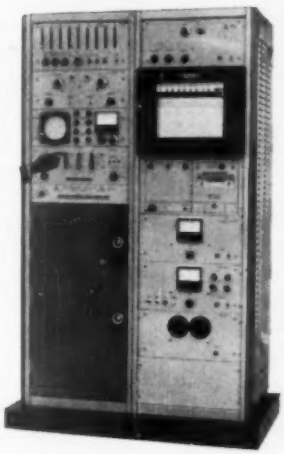

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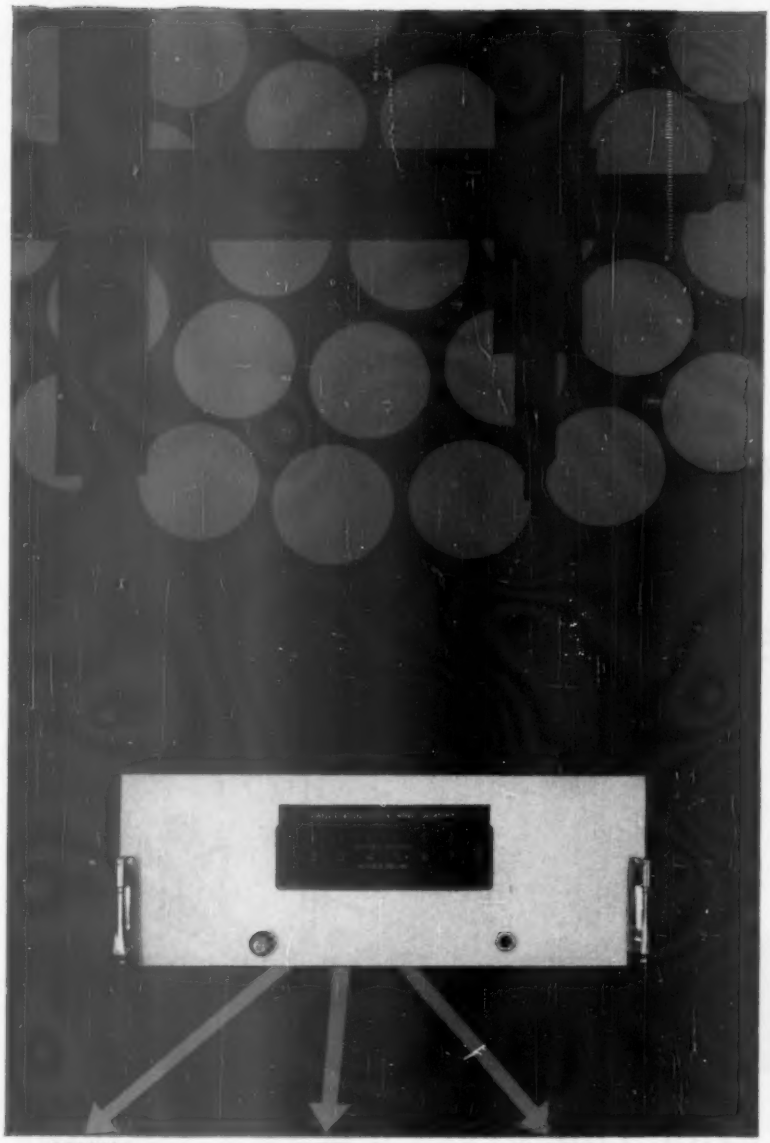

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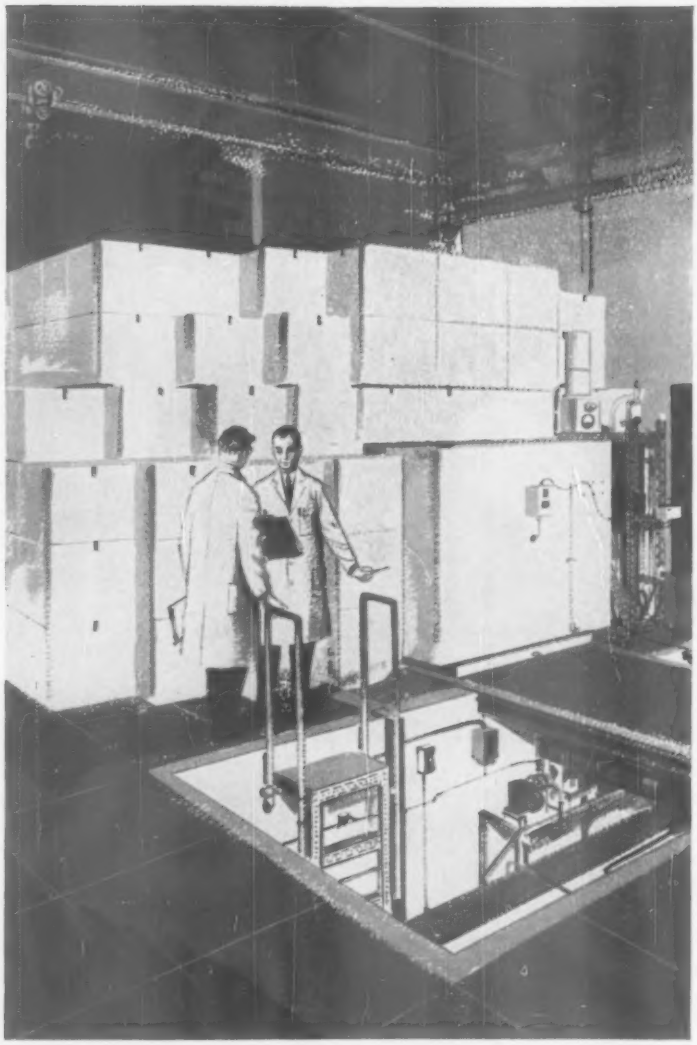

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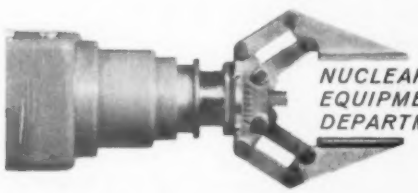

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Inconel, nickel-chromium alloy, has been added to Superior's line of Nuclear Quality Heat Exchanger Tubing. This analysis offers unusually high stress corrosion resistance. It is highly resistant to intergranular and selective attack in spite of applied or residual stress and exposure to liquid and vapor phase water, even if the primary or secondary water contains oxygen and chloride ions. Typical of its resistance to corrosion is the following: at 650°F, 25 ft/sec flow, the corrosion rate is less than 12 mg/(dm^2)/month. In Superior's Inconel tubing, cobalt and carbon content are held to restrictive levels. Control of cobalt content reduces radiation hazards.

For particulars on Nuclear Quality Inconel Alloy Heat Exchanger Tubing, write for STC-107, Superior Tube Company, 2027 Germantown Ave., Norristown, Pa.

*Trademark of the International Nickel Co.

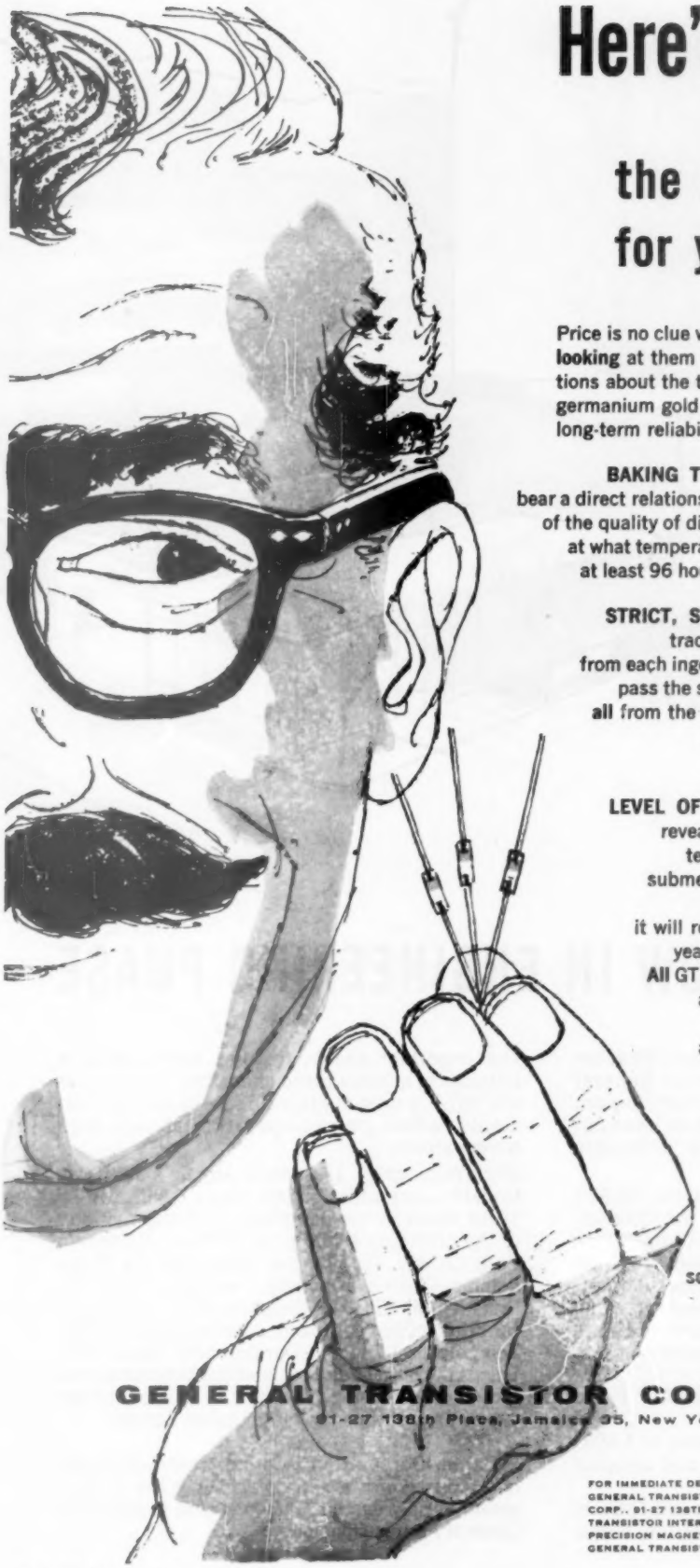
Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST



Here's how to pick the best DIODES for your money

Price is no clue when diodes sell for about the same, and just **looking** at them tells nothing. But if you ask the right questions about the three key factors in the production of **quality** germanium gold bonded diodes, you have your clues to more long-term reliability for your money. Here they are:

BAKING TIME AND TEMPERATURE
bear a direct relationship to long-term stability. You get a measure of the quality of diodes by asking: "How long do you bake, and at what temperature?" (**All** GT diodes are baked at 140°C for at least 96 hours—the highest and longest in the industry!)

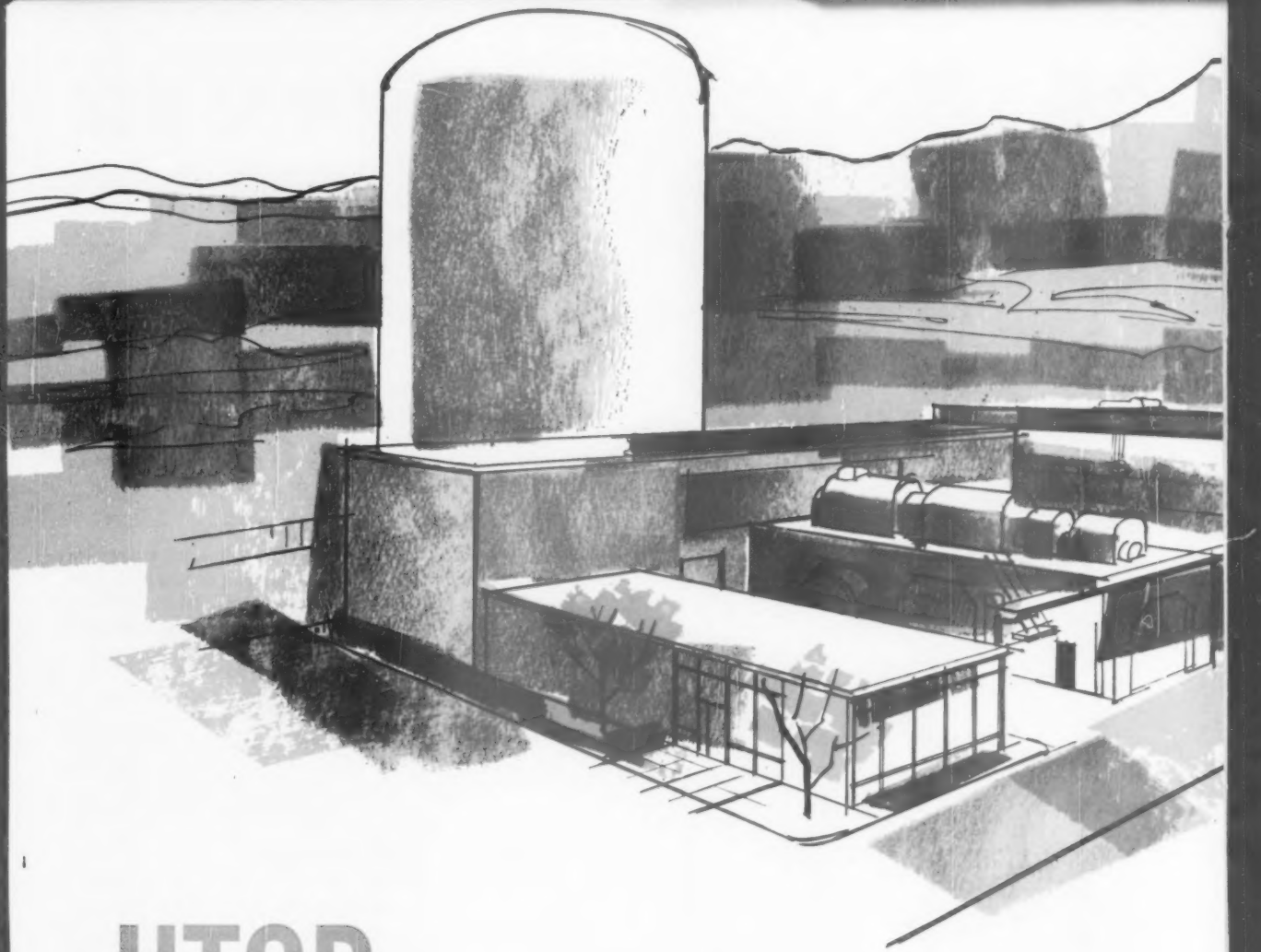
STRICT, STATISTICAL, HISTORY LOGGING
traces the progress of every single wafer made from each ingot of germanium. At GT, if a few wafers fail to pass the stringent GT quality tests along the way, then **all** from the ingot are suspect and can be identified and pulled out. There are no "stowaways" in a shipment of GT quality diodes.

LEVEL OF TESTING STANDARDS
reveals the level of quality. Ask about "everyday" test standards. (In the GT Seal Test, diodes are submerged in a penetrant-dye solution for 24 hours under 75 psi. This test is so sensitive that it will reveal a leak so small it would take over 300 years for 1 cc of gas to diffuse through the case.) **All** GT quality tests—100% electrical, 100% shock and vibration, and 100% temperature cycling —are at the highest industry level... and as a final mark of quality, the color bands on GT Germanium Gold Bonded Diodes are baked on to stay.

GT is equipped to supply diodes tested to individual customer requirements, such as JAN Qualification Inspection Tests and many others.
To get the full measure of quality in Germanium Gold Bonded Diodes, see your GT representative; or write directly to the company with know-how **NOW.**

GENERAL TRANSISTOR CORPORATION
91-27 138th Place, Jamaica 35, New York

FOR IMMEDIATE DELIVERY FROM STOCK, CONTACT YOUR NEAREST AUTHORIZED GENERAL TRANSISTOR DISTRIBUTOR OR GENERAL TRANSISTOR DISTRIBUTING CORP., 91-27 138TH PLACE, JAMAICA 35, NEW YORK. FOR EXPORT: GENERAL TRANSISTOR INTERNATIONAL CORP., 91-27 138TH PLACE, JAMAICA 35, NEW YORK. PRECISION MAGNETIC RECORDING HEADS AVAILABLE FROM GENERAL TRANSISTOR WESTERN CORP., 6110 VENICE BLVD., LOS ANGELES, CALIF.



HTGR/NOW IN ENGINEERING PHASE

The High Temperature Gas-cooled Reactor (HTGR), now under development at General Dynamics Corporation's General Atomic Division, has as its promising goal an important short cut to the nation's objective of truly economic nuclear power.

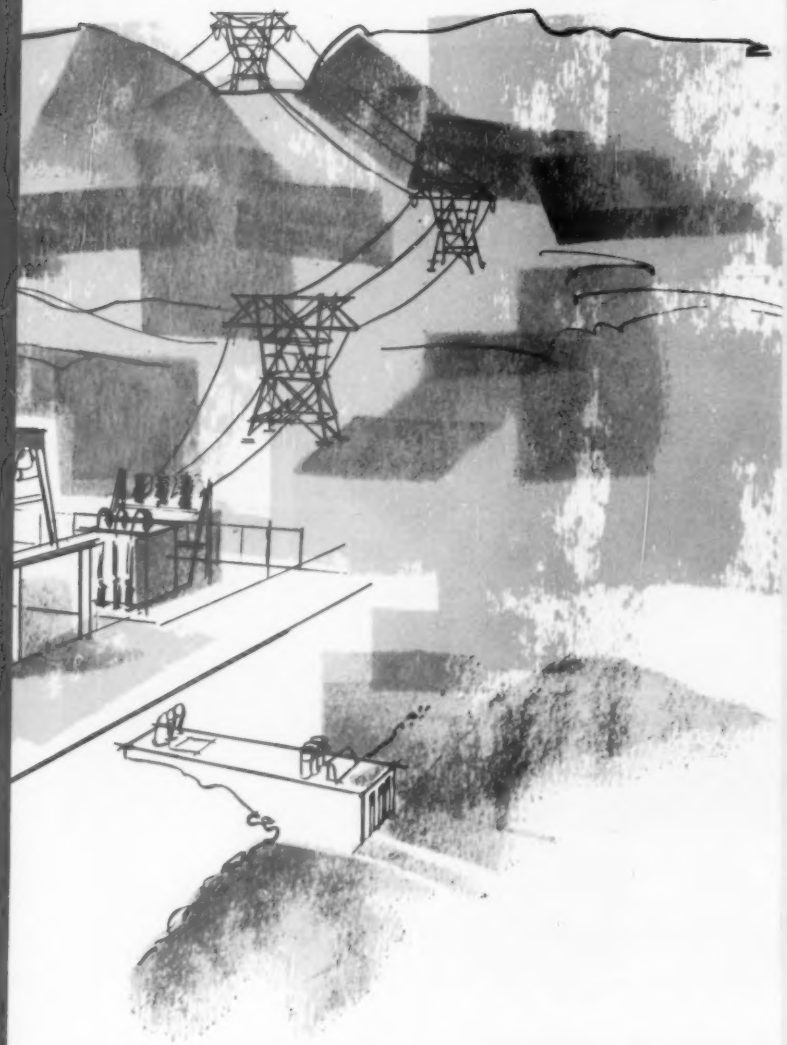
A prototype HTGR plant designed for 40,000 KW(E) is now under development for Philadelphia Electric Company and the High Temperature Reactor Development Associates, Inc. The high performance HTGR system — the result of an extensive development program at General Atomic during the past three years — embodies the following important design characteristics to achieve economic nuclear power:

1. Modern steam conditions of 1000° F and 1450 psi.
2. A helium gas outlet temperature of 1380° F resulting in an economical and compact heat exchanger system.
3. Fuel burnup of the homogeneous UThC fuel in the 50,000-100,000 MWD/ton range.

The important design features which make it possible to achieve these characteristics include the HTGR's unique graphite fuel-moderator elements, which permit operation at very high temperatures.

Work in progress at General Atomic's John Jay Hopkins Laboratory in San Diego, Calif., will by 1963 result in the completion of construction* of the prototype HTGR plant at Peach Bottom in York County, Pa., on the system of the Philadelphia Electric Company. Associated with the Philadelphia Electric Company in the project are 52 other utility companies comprising the High Temperature Reactor Development Associates. This is the largest and most widely representative group of utilities to support a single nuclear power project thus far in the United States.

*Bechtel Corporation is prime contractor-engineer constructor for the plant, with the nuclear steam supply system designed and supplied by General Atomic Division.



Member companies of High Temperature Reactor Development Associates include:

Alabama Power Company
Arizona Public Service Company
Arkansas Power & Light Company
Atlantic City Electric Company
Baltimore Gas and Electric Company
California Electric Power Company
Central Illinois Electric and Gas Company
Central Illinois Light Company
Central Illinois Public Service Company
Central Louisiana Electric Company
Central Power and Light Company
Cincinnati Gas & Electric Company
Cleveland Electric Illuminating Company
Delaware Power & Light Company
Detroit Edison Company
Gulf Power Company
Gulf States Utilities Company
Hawaiian Electric Company, Ltd.
Idaho Power Company
Illinois Power Company
Iowa Public Service Company
Kansas City Power & Light Company
Kansas Power and Light Company
Kentucky Utilities Company
Louisiana Power & Light Company
Mississippi Power Company
Mississippi Power & Light Company
Missouri Public Service Company
Montana Power Company
New Orleans Public Service, Inc.
New York State Electric & Gas Corporation
Niagara Mohawk Power Corporation
Pacific Gas and Electric Company
Pacific Power & Light Company
Pennsylvania Power & Light Company
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Public Service Company of Colorado
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Public Service Electric and Gas Company
Puget Sound Power & Light Company
Rochester Gas and Electric Corporation
St. Joseph Light & Power Company
San Diego Gas & Electric Company
Sierra Pacific Power Company
Southern California Edison Company
Southwestern Electric Power Company
United Illuminating Company
Utah Power & Light Company
Washington Water Power Company
West Texas Utilities Company

GENERAL ATOMIC
DIVISION OF **GENERAL DYNAMICS**

Openings For Engineers In Nuclear Reactor Design

Rapid expansion of the High Temperature Gas-cooled Reactor and other major programs at General Dynamics' General Atomic Division has created increased engineering activity leading to openings, including senior positions, in reactor design and development.

In the important area of nuclear engineering, immediate openings exist for men qualified to perform thermal analyses of reactor cores . . . reactor design neutronic calculations . . . analyses of reactor and system controls . . . structural design of reactor components . . . and the design of mechanisms such as control drives and fuel charging systems associated with the reactor. There are also openings in the HTGR program for qualified metallurgists, physicists, chemists and chemical engineers, materials specialists, mathematicians, and programmers.

Inquiries are also invited from senior men qualified to conduct studies of new applications of nuclear energy in the power generation, transportation, space propulsion, and chemical fields.

Besides HTGR, other programs presently in progress at General Atomic include the MGCR gas-cooled reactor and closed-cycle gas turbine system for merchant ship propulsion . . . TRIGA reactors for research, training, and isotope production . . . small nuclear power systems . . . test reactors . . . nuclear power for space vehicles . . . direct conversion of heat to electricity . . . and research in controlled thermonuclear reactions.

For further information on these openings, write: Manager of Personnel, General Atomic, P. O. Box 608-S, San Diego 12, California.

Reactor Core — High Temperature Gas-cooled Reactor

São Paulo

Another reactor control "systems engineered" by L&N

Here's another example of L&N's "complete systems" approach to reactor operation—the controls for the Sao Paulo Institute de Energia Atomica Research Reactor. Designed for this "swimming pool" reactor, which was built by the Babcock & Wilcox Company, the instrumentation is made up of standard L&N precision components.

L&N Speedomax® G recorders measure important temperatures and monitor area radioactivity. Speedomax H recorders chart the nuclear functions at all power levels. Electromax® controllers regulate conductivity and activate safety signals for alarm purposes. A P.A.T. servo-amplifier positions the control rod to regulate reactor power levels, while an 18-range micro-microammeter indicates flux levels from start-up to scram. Physically, these instruments and their equipment constitute the integrated control for the Sao Paulo reactor. But such a system could not be truly effective without the important L&N intangibles—engineering consultation, design service, and overall coordinated planning—so vital to thoroughly sound reactor control.

For our new booklet "Nuclear Power Reactor Control Systems," write Leeds and Northrup Co., 4936 Stenton Ave., Philadelphia 44, Pa.

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Instruments — Automatic Controls • Furnaces

Tires that last ten years . . .
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Tougher plastics . . .
these products of the future are subjects for experimentation today. Many industries and research institutions are now looking to cobalt 60 gamma irradiation as the key to new horizons.
Gammacell 220

Photo courtesy Textile Research Center, School of Textiles, North Carolina State College, Raleigh, N.C.

For your gamma irradiation experiments, choose the GAMMACELL 220

with source strengths to suit your purpose

IT'S PROVEN — Already in use in several countries and in many fields of research.

IT'S SELF-CONTAINED — No auxiliary shielding required . . . Buy it as just another piece of laboratory equipment. Easy to move to a new location as a change in plans requires.

IT'S SAFE — By construction, it is inherently safe to operate. Overexposure would have to be deliberately planned.

IT'S SIMPLE — No complex electrical equipment to break down. Any technician can readily operate it with minimum instruction.

FOR FULL DETAILS ON THE GAMMACELL 220, KILOCURIE COBALT 60 OR OTHER ISOTOPE EQUIPMENT, PLEASE WRITE TO:—

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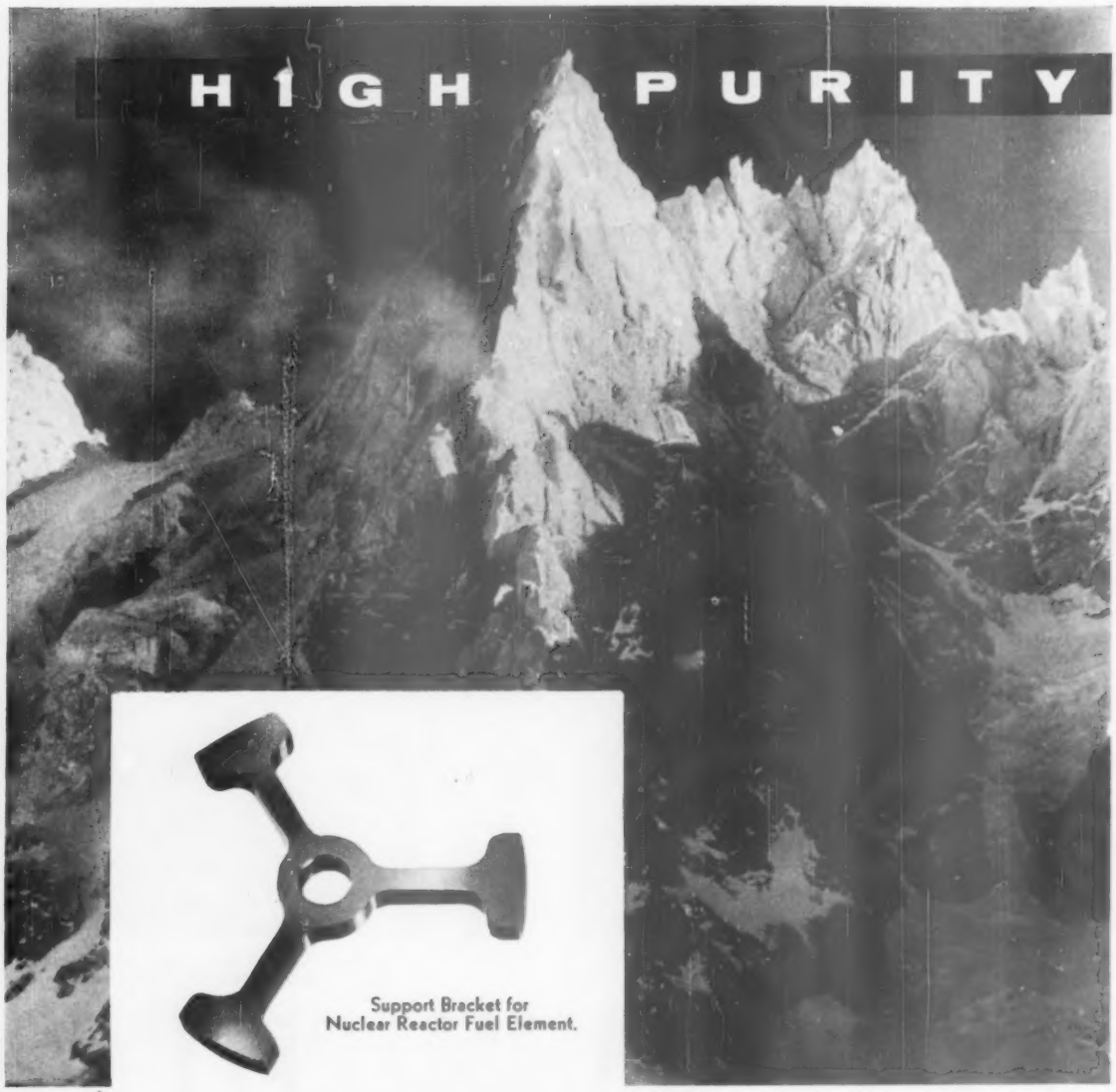

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Powdered, molten metal blocks, or sintered into sheets, bars, tubes or finished products.

PECHINEY Division Applications Atomiques
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One of a series

Resolving the driver-car-road complex

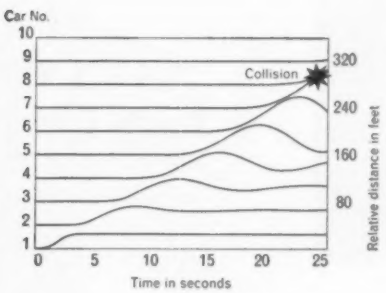
The manner in which vehicles follow each other on a highway is a current subject of theoretical investigation at the General Motors Research Laboratories. These studies in traffic dynamics, coupled with controlled experiments, are leading to new "follow-the-leader" models of vehicle interaction.

For example, conditions have been derived for the stability of a chain of moving vehicles when the velocity of the lead car suddenly changes – a type of perturbation that has caused multiple collisions on modern superhighways. Theoretical analysis shows that the motion of a chain of cars *can be stable* when a driver accelerates in proportion to the relative velocity between his car and the car ahead. The motion is always unstable when the acceleration is proportional only to the relative distance between cars. Experimentally, GM Research scientists found that a driver does react mainly to relative velocity rather than to relative distance, with a sensitivity of reaction that increases with decreasing distance.

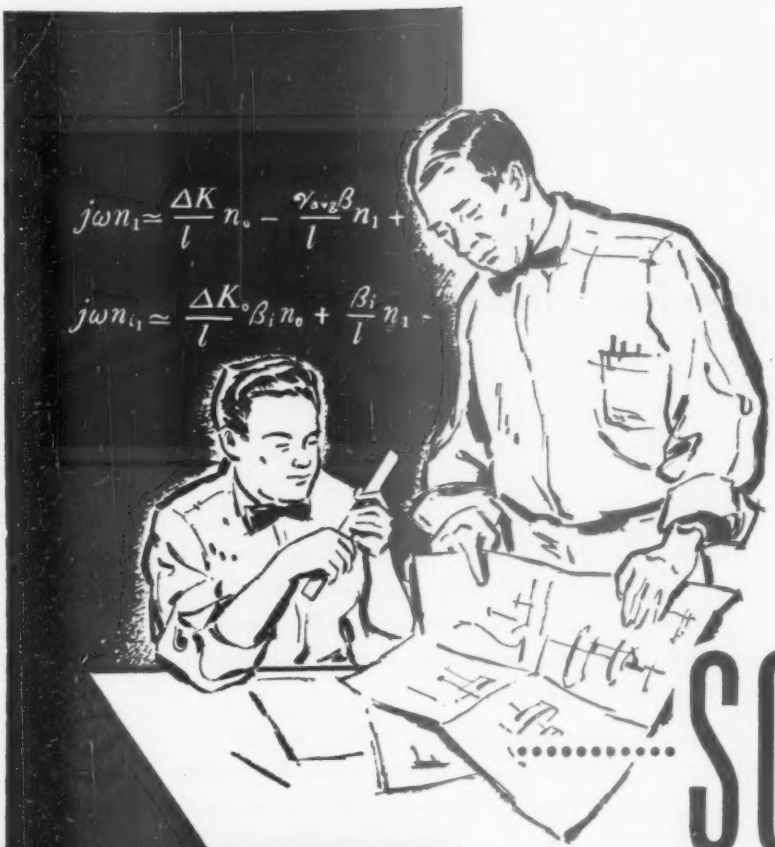
Traffic dynamics research such as this is adding to our understanding of intricate traffic problems – what causes them, how they can best be resolved. The study is an example of the ways GM Research works to make transportation of the future more efficient and safe.

General Motors Research Laboratories

Warren, Michigan



Relative positions of 10 hypothetical cars after lead car goes through maneuver. Amplitude of instability increases, resulting in a collision between 7th and 8th cars.



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. . . all but the necessary High Pressure Research Tools

and there's where Autoclave Engineers, Inc. comes into the picture to help you reach your objective.

For more than a decade, we have been designers and producers of high pressure equipment . . . valves, reactors, stirred autoclaves, pumps, pressure vessels and related equipment.

While your project is in the planning stage, it will pay you to consult with us on the engineering design and most economical manufacturing procedures for the high pressure research equipment you need. We can help you!

AUTOCLAVE ENGINEERS Designs and Builds High Pressure-High Temperature Equipment Such As—

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Complete Package Systems (Including Panel Board For Control and Instrumentation) Such As—

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- Diffusion Bonding
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- Shock Tube Systems

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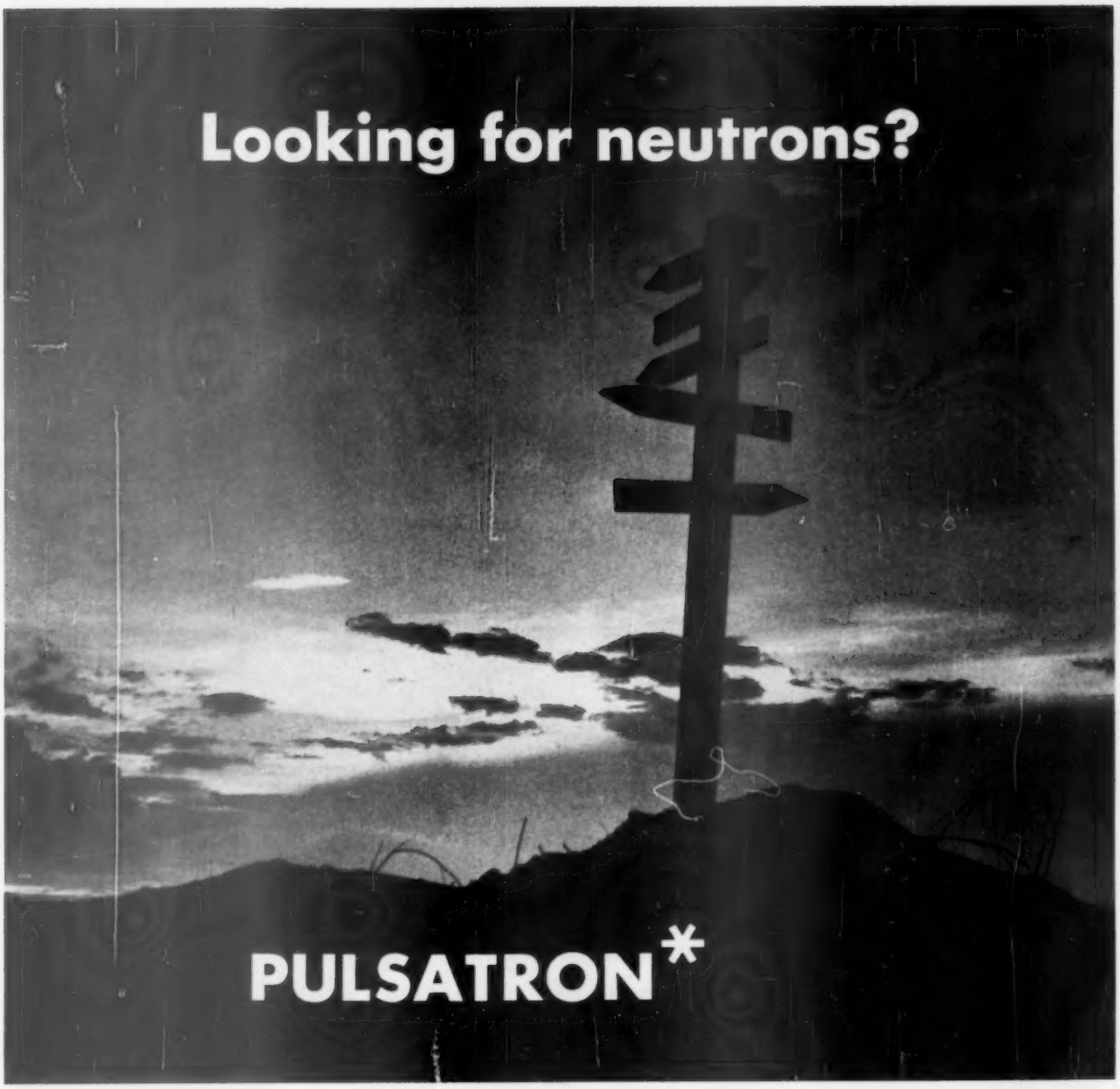

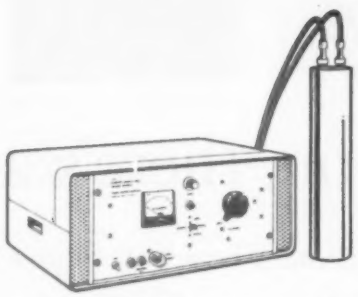

* **the Kaman neutron source**

small - lightweight - portable

10^7 neutron/pulse - nominal.
5 microseconds — pulse length.
Adjustable - 1-10 pulses/sec.
H^3 (d, n) He^4 reaction.
Accelerator Unit — 4" OD x 18" long.
Control Unit — 21¾" x 15¼" x 10½".

The NT-60-8 Pulsed Neutron Generator Assembly . . . *an Exclusive Development by*

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Research and Development in Nuclear Weaponry and Instrumentation.

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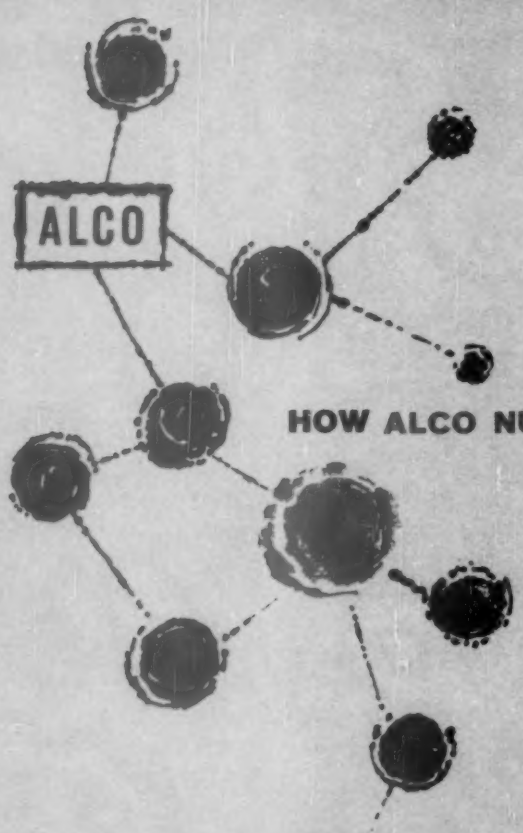
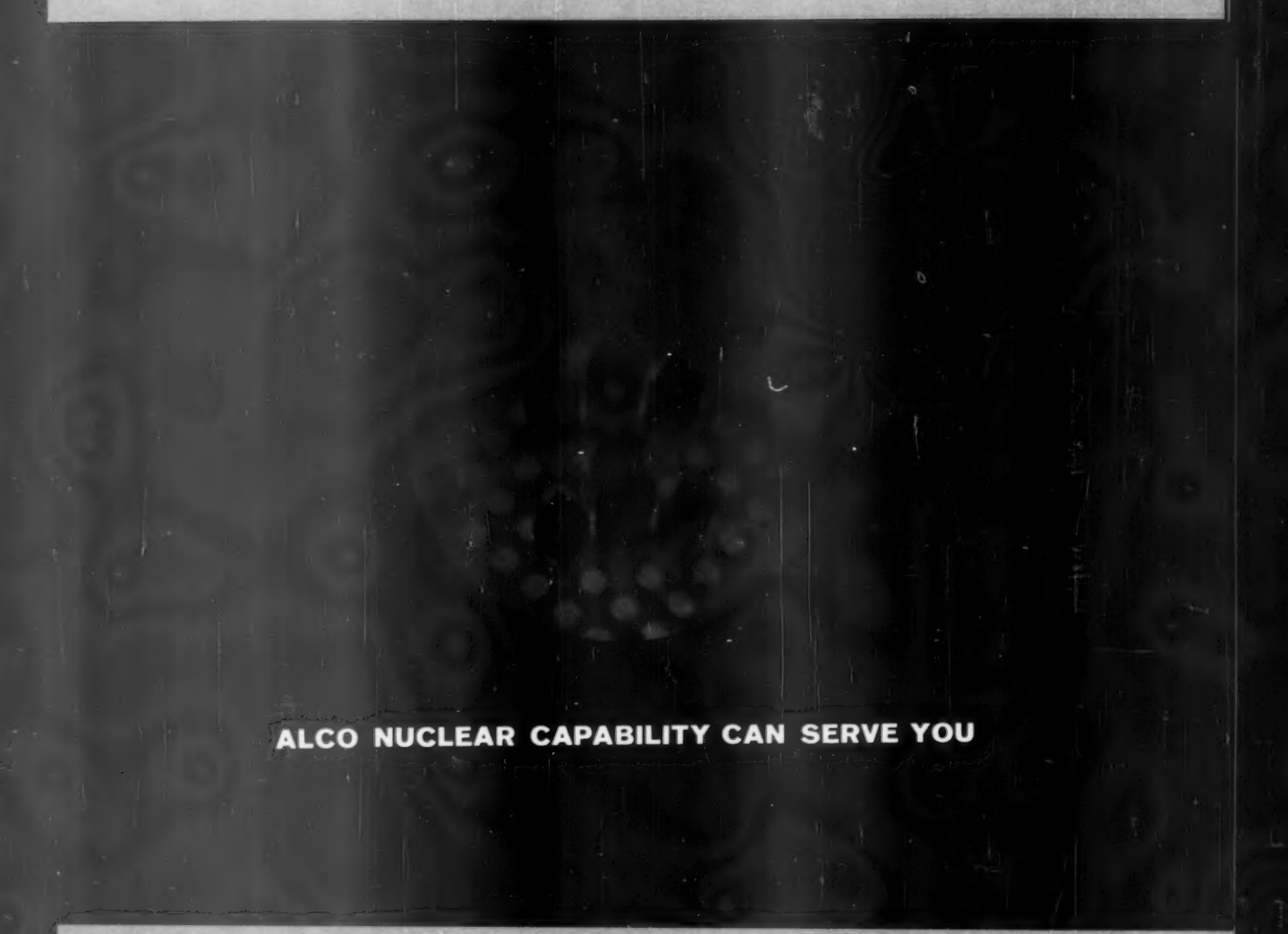


HOW ALCO NUCLEAR CAPABILITY CAN SERVE YOU

ALCO OFFERS YOU COMPLETE INTEGRATION

1. CONCEPTUAL DESIGN
2. COMPLETE NUCLEAR ENGINEERING
3. DEVELOPMENT
4. FABRICATION
5. ERECTION, START-UP AND OPERATION

ALCO can start with the glimmer of a nuclear reactor in your mind's eye, then evolve the concept, design it, engineer it, test it, build it, erect it, and put it to work. ALCO has already designed and built three nuclear power plants, and participated in the design or manufacture of practically every U.S. reactor system. This experience can prove invaluable to you in setting up a nuclear plant. These services are available:



ALCO NUCLEAR CAPABILITY CAN SERVE YOU

$$K_{eff} = \frac{\epsilon p K_{th}}{(1+B^2L^2)(1-B^2\tau)} + \frac{\epsilon(1-p)K_f}{(1+B^2\tau)}$$

1. CONCEPTUAL DESIGN

Market analysis
Plant concepts
Reactor economics
System optimization
Fuel development
Radiation protection
Radiochemistry
Analytical techniques
Reactor coolants and thermal studies
Metallurgy
Mechanisms

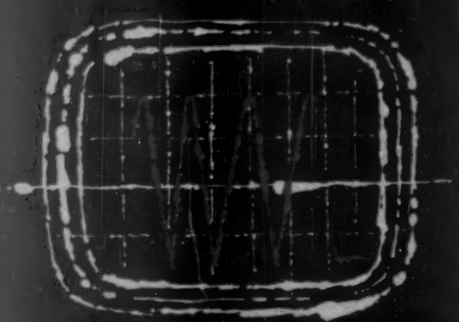
ALCO

2. COMPLETE NUCLEAR ENGINEERING

Core physics
Shielding
Thermal and fluid dynamics design
Mechanical design
Systems engineering
Instrumentation and control
Health physics
Radiochemical studies
Computation
Materials selection
Hazards presentations

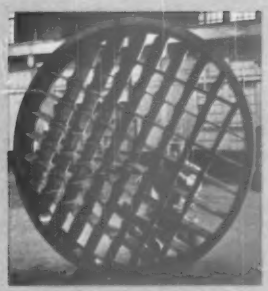
ALCO NUCLEAR CAPABILITY CAN SERVE YOU

3. DEVELOPMENT

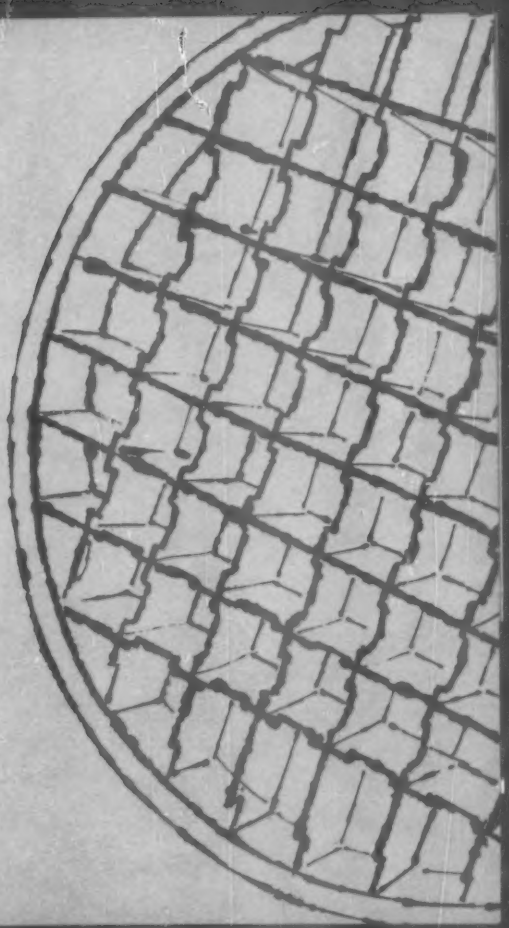


- Criticality facility
- Thermal lab
  - Thermal and fluid dynamics studies
- Metallurgical lab
  - Destructive and non destructive testing
  - Welding development
  - Fuel element fabrication
- Mechanical lab
  - Life tests
  - Stress tests
  - Strength tests
  - Core flow tests
  - Fuel element and control rod stress tests
  - Mechanical apparatus testing
  - Control-rod drive reliability tests
- Radiochemistry lab
  - Decontamination
  - Chemical analysis
  - Purification and clean up
  - Coolant treatment

4. FABRICATION



Reactor vessels and internals
Closures
Control-rod drives
Steam generating equipment
Pressure vessels and pressurizers
Piping
Heat exchangers
Fuel-handling mechanisms and tools
Spent-fuel containers
Modular packaging



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5. ERECTION, START-UP AND OPERATION

Erection supervision
Non-critical and critical test
Operation
In-plant development
Personnel training
Performance evaluation
Technical manuals

ALCO NUCLEAR PLANT EXPERIENCE ASSURES DEPENDABILITY

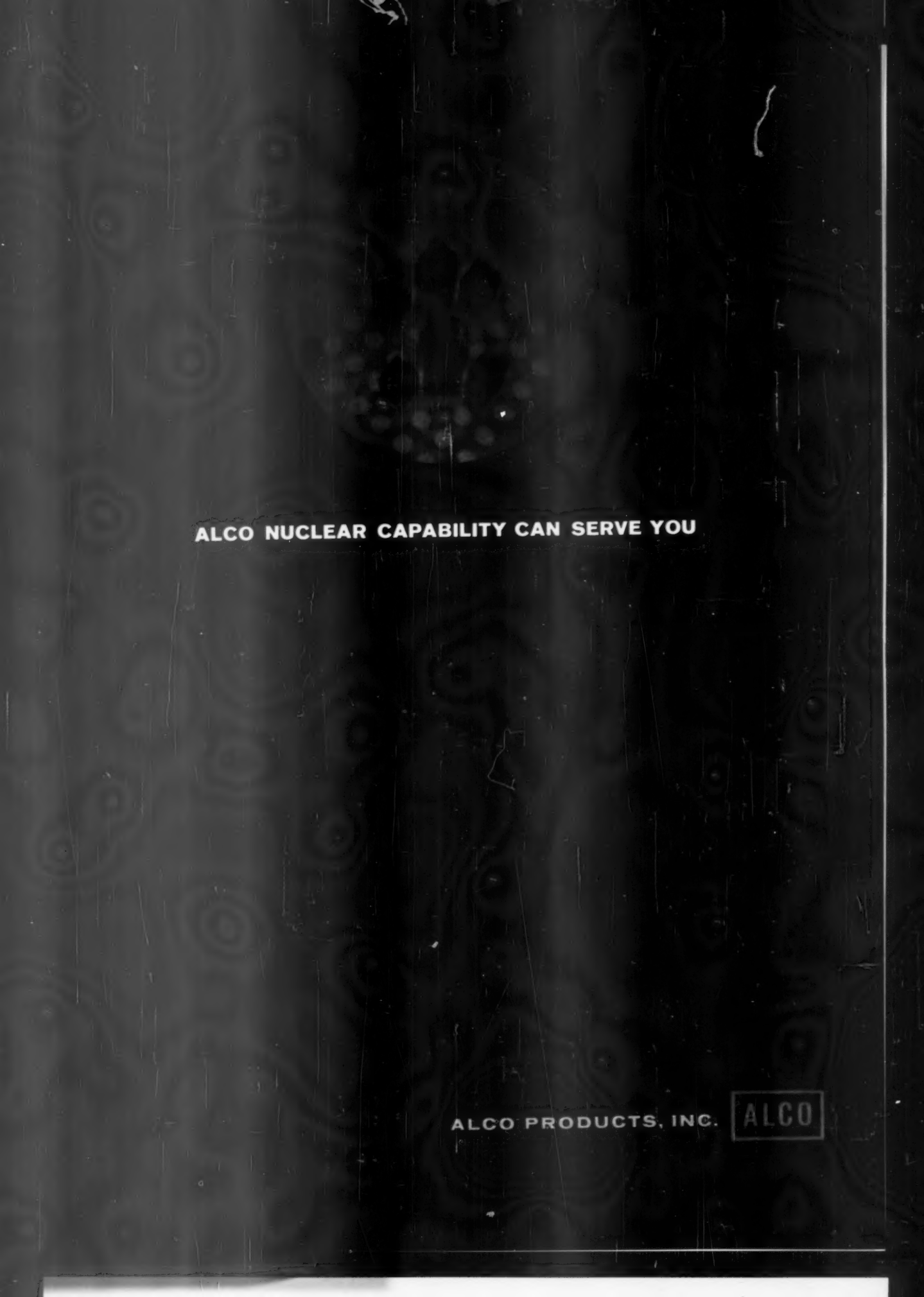
From design to operation, ALCO is providing integrated services for these current nuclear reactor systems.

DESIGNATION	DESCRIPTION	MODERATOR, COOLANT	REACTOR FUEL	THERMAL POWER RATING UP TO:	STATUS 1/1/60
SM-1	First prototype, military package power reactor	Press. H_2O	Highly enriched UO_2 dispersed in stainless	10 MW	In operation 3 years
SM-1A	First field unit, military package power reactor	Press. H_2O	Highly enriched UO_2 dispersed in stainless	20 MW	Erection to be completed mid-1960
SM-2	Prototype military reactor for high-quality power generation	Press. H_2O	Highly enriched UO_2 dispersed in stainless	25 MW	Final design completed mid-1960
PM-2A	Portable military power reactor for remote frigid location.	Press. H_2O	Highly enriched UO_2 dispersed in stainless	10 MW	Installation scheduled summer, 1960

ALCO

ALCO PRODUCTS, INC. has designed pressurized-water and gas-cooled nuclear plants to 125,000 kw for stationary and marine application. In addition, ALCO has supplied nuclear components for nine out of ten U. S. nuclear systems.

ALCO PRODUCTS, INC.
Nuclear Energy Engineering Dept.,
Schenectady, N.Y.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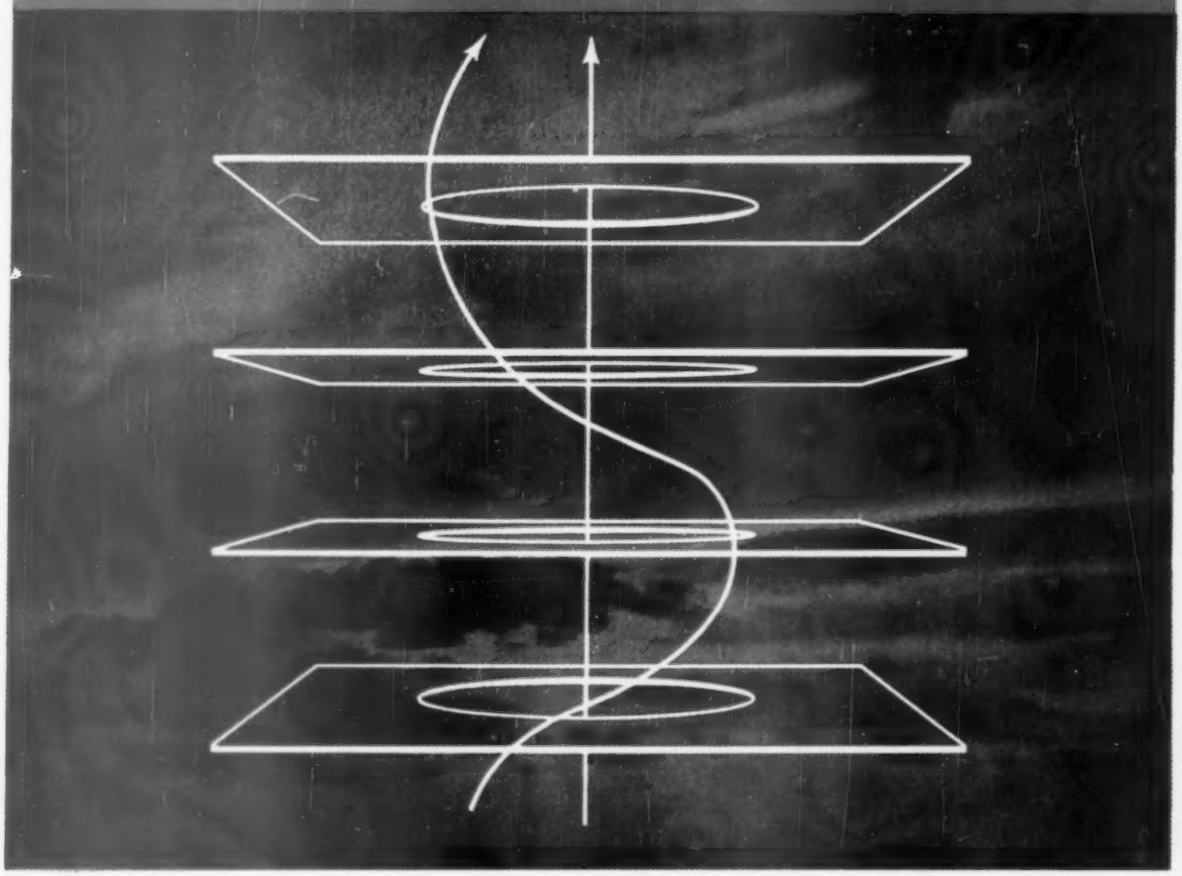

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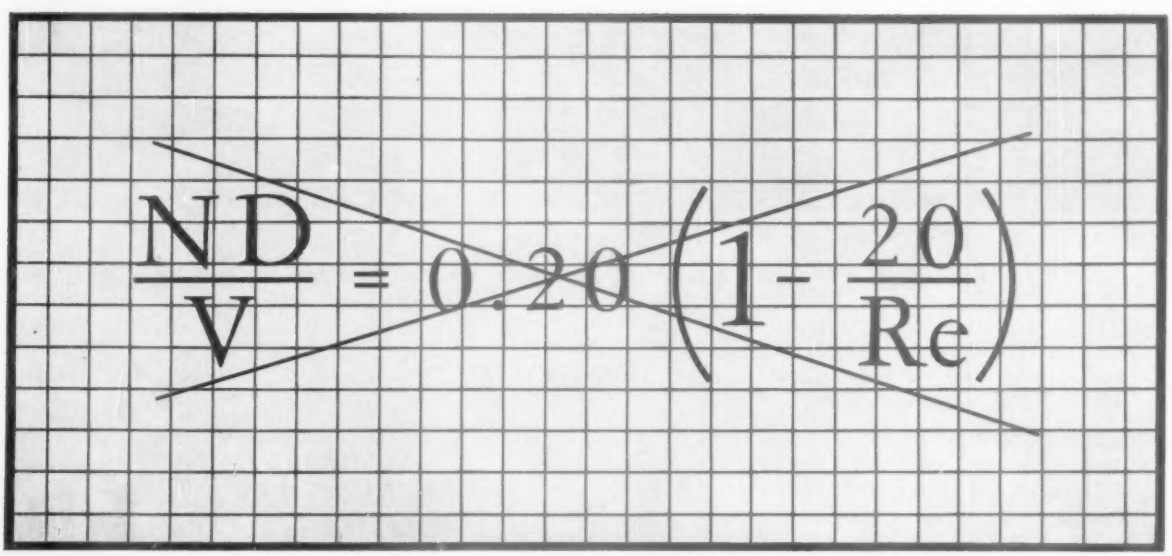
REACTOR COMPONENT VIBRATION

If you are a mechanical, electrical or chemical engineer interested in a career in nuclear engineering and are a U. S. Citizen, Bettis Atomic Power Laboratory offers a dynamic program in nuclear system design and test. For additional information, write to: Mr. M. J. Downey, Dept. B-23, Bettis Atomic Power Laboratory, Westinghouse Electric Corporation, P.O. Box 1526, Pittsburgh 30, Pa.



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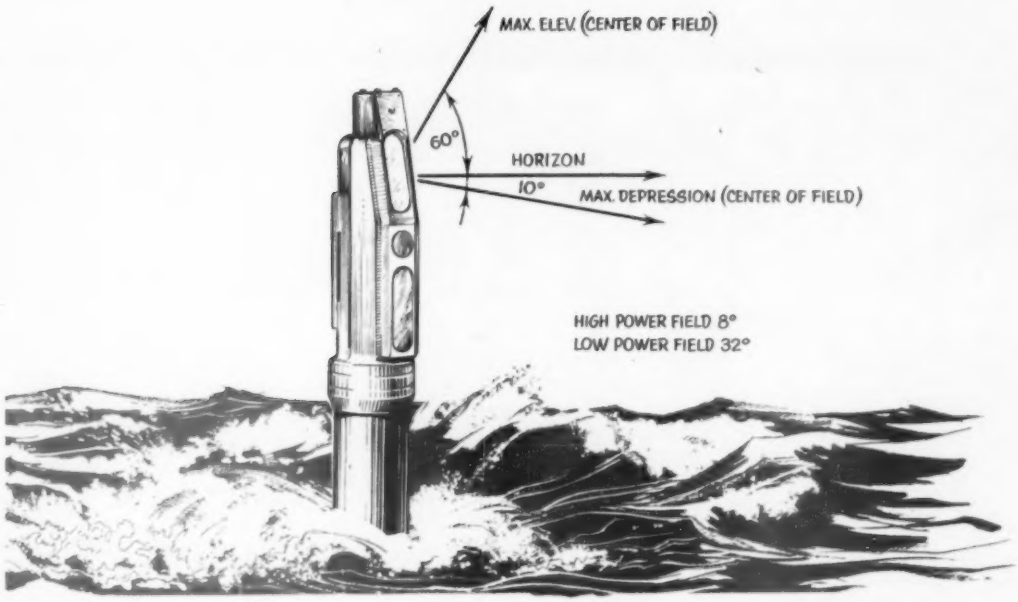
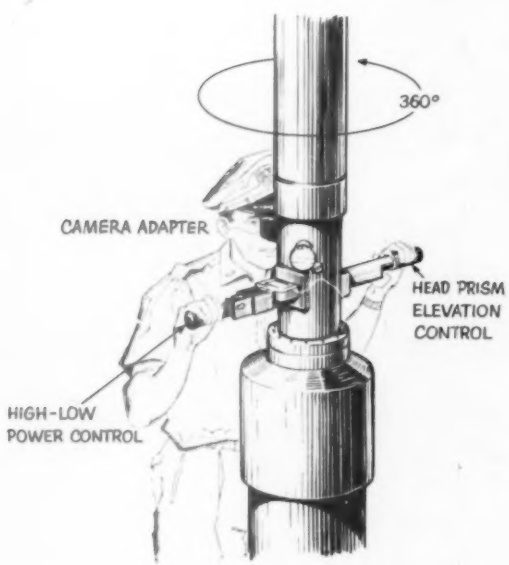


The Nuclear Navy has Kollmorgen eyes

The USS NAUTILUS and her sister subs in our nuclear navy are each fitted with two or three modern periscopes designed and manufactured by Kollmorgen. These naval "eyes" are precise optical instruments over forty feet long with controls and components that solve difficult problems of viewing, computation and tactics.

Kollmorgen has had notable successful experience developing optical inspection and alignment equipment. High speed projection lenses, industrial periscopes, mechanical and electronic controls for viewing instruments are all typical of advanced Kollmorgen production.

Write on your company letterhead for a fully illustrated, twenty-four page brochure describing Kollmorgen's experience, skills and facilities.



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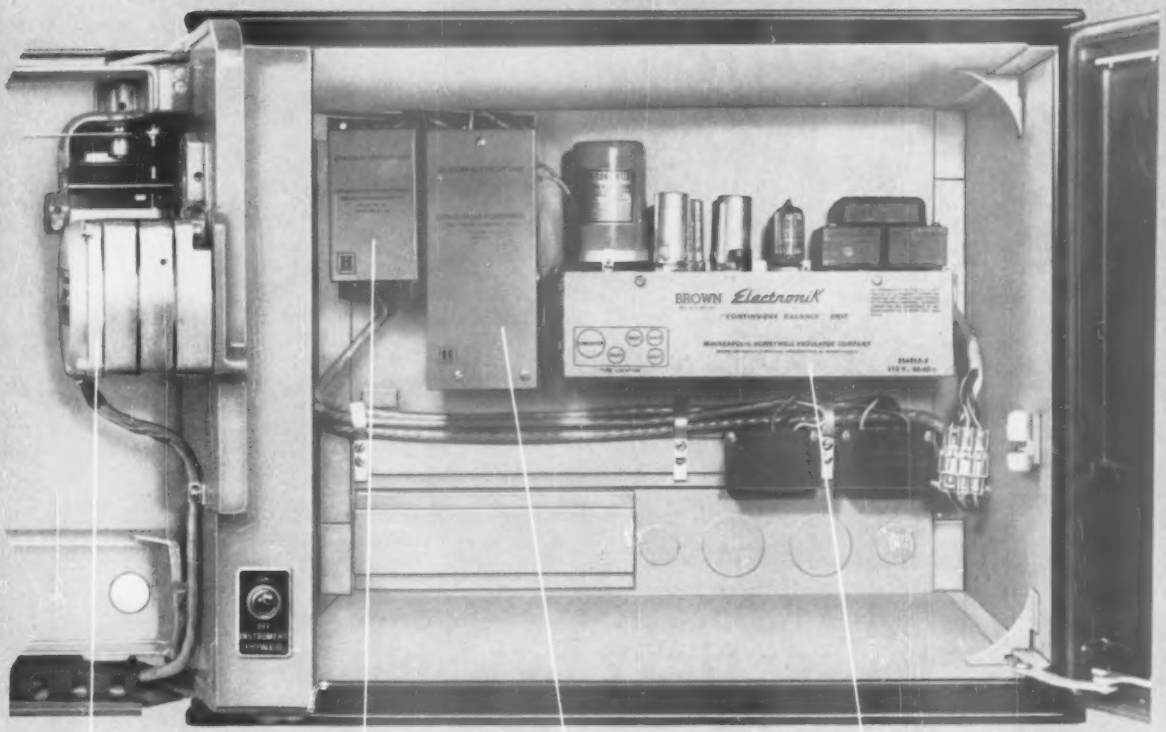
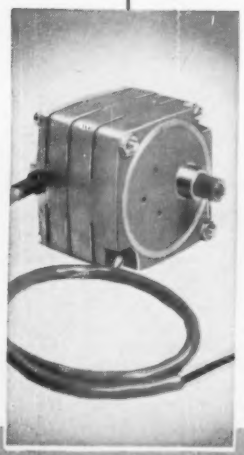
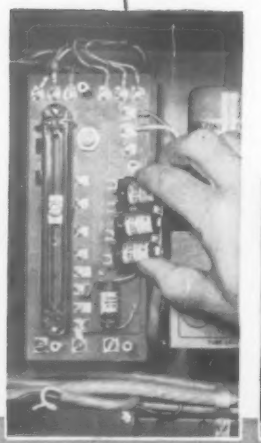


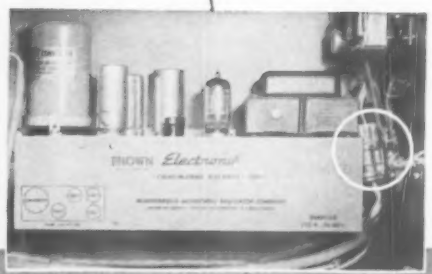


Servo Motor has sectional housing, leakproof oil wick, printed circuits for simplified servicing. Any major part can be replaced in 2 minutes.

Constant Voltage Module—Uses Zener diodes and an ambient temperature compensator to replace standardizing mechanism.



Measuring Circuit Module—Contains easily-changed range spool panels and vernier adjustment. Range is changed simply by replacing screw-dip panels of fixed resistors.



Amplifier Module—Quick-connect design permits fast, easy removal for servicing and replacement. Circle shows quick connect plug.

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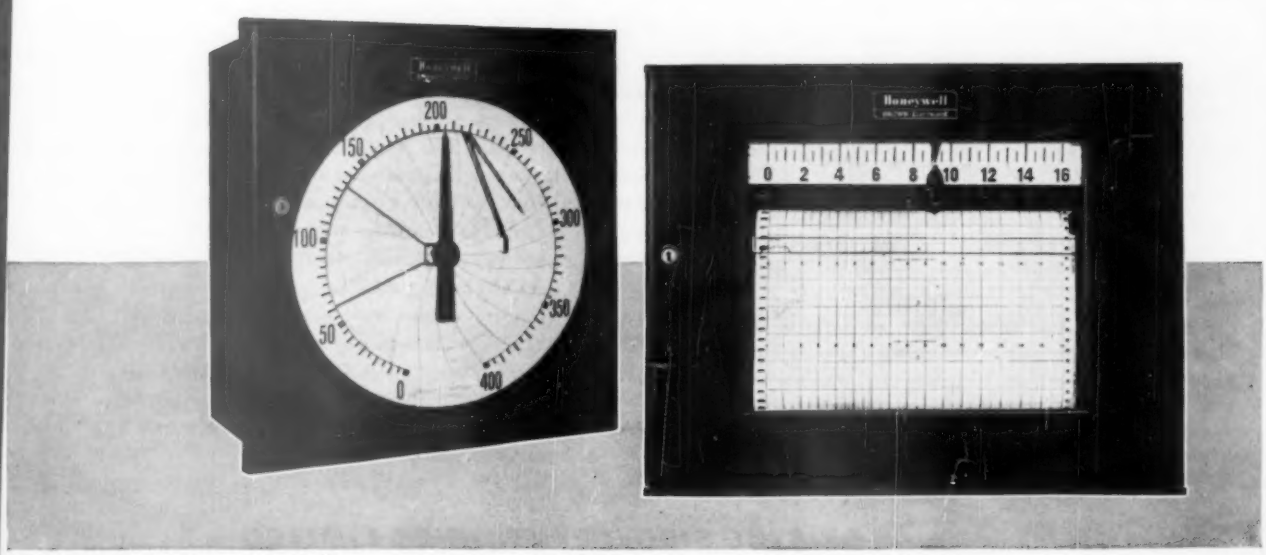

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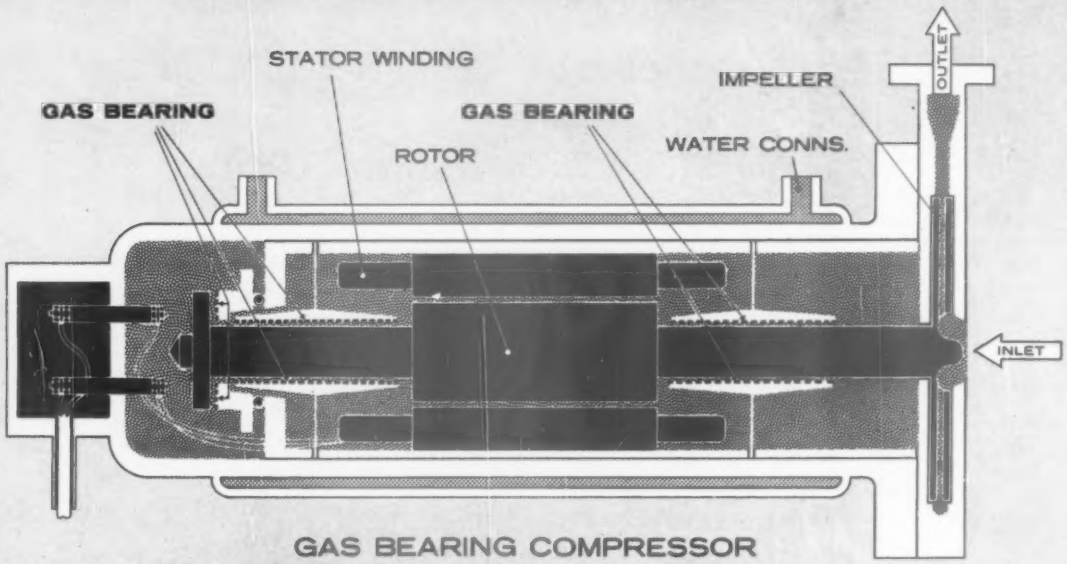

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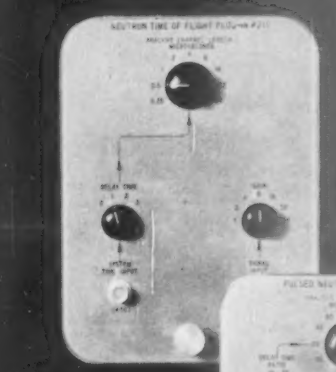
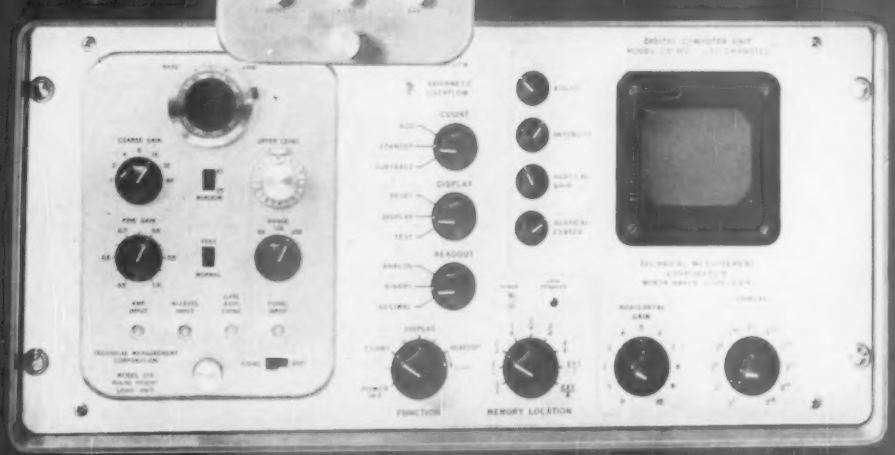


time-of-flight plug-in

pulsed neutron plug-in

PLUG-IN LOGIC



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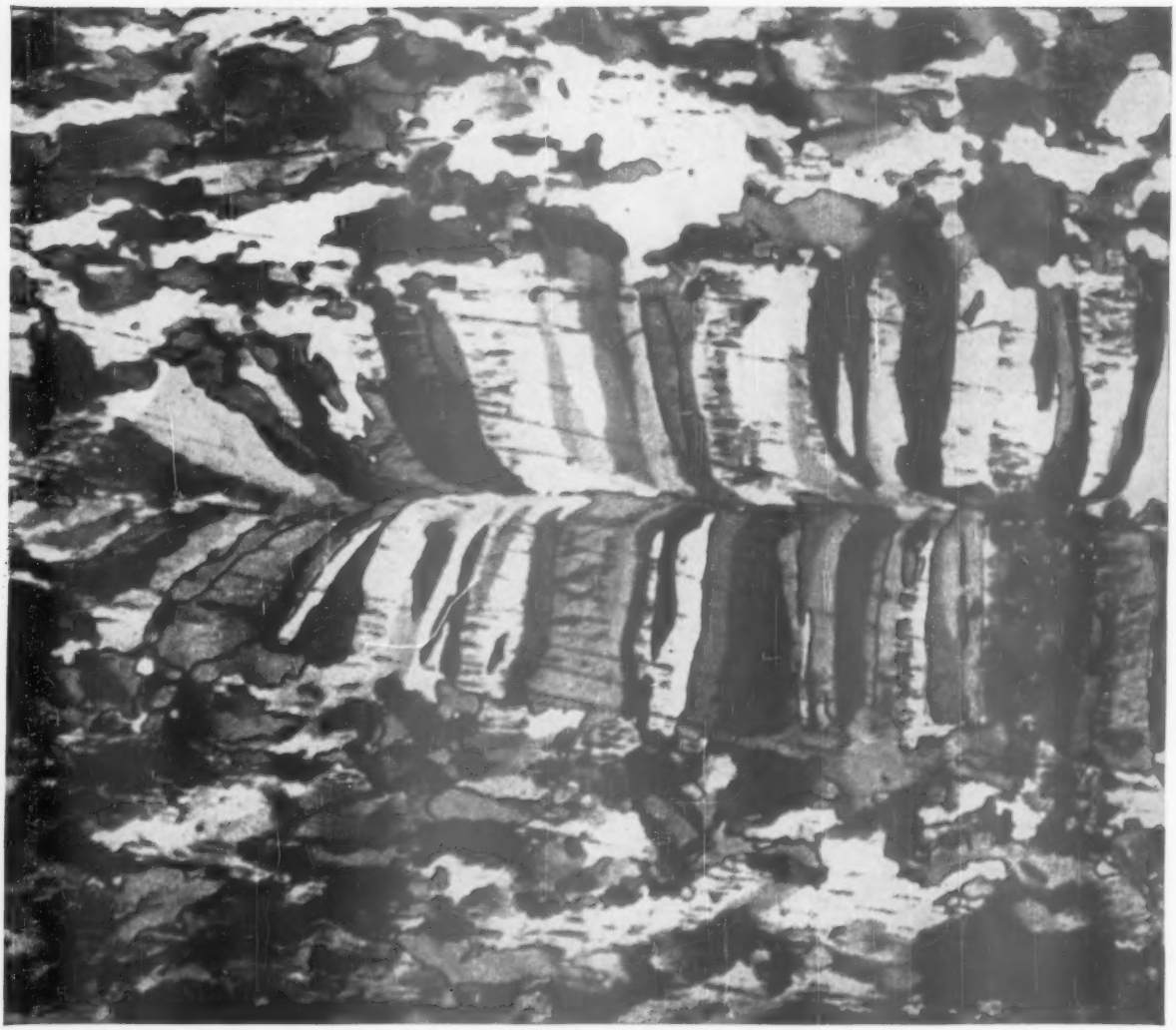

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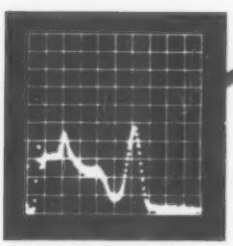
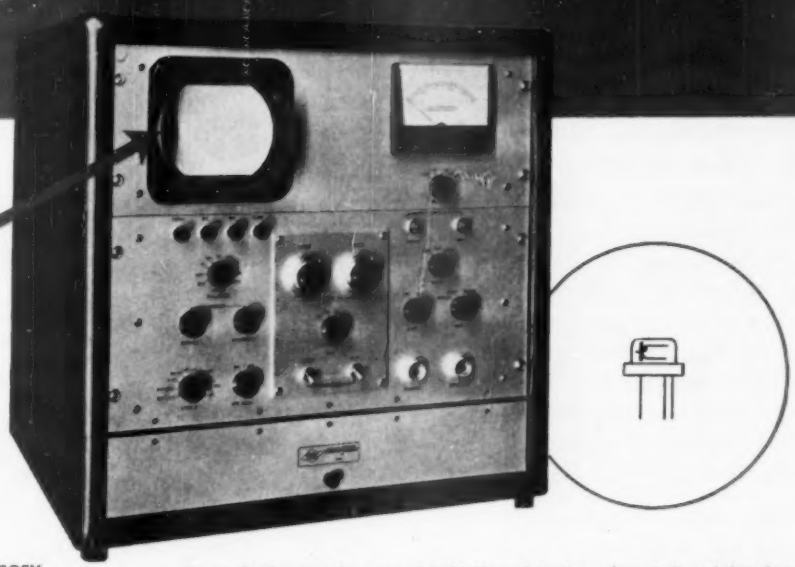


Cesium 137 spectrum photographed from CRT display of Model 34-8.



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Recent developments by users of Multi-Channel Analyzers have indicated that there is a need for an accessory device to transfer data from a conventional pulse height analyzer to an external storage element and reverse, i.e., put information stored externally into the pulse height analyzer.

The purpose of this accessory would be to provide the data storage and correction function with a minimum of external equipment. A system to accomplish these functions is now being developed by RIDL for use with the Model 34-8 Transistorized 200 Channel Analyzer. This system is intended to be used to substract arbitrary amounts of standard spectra from composite samples, to remove large peaks contributed by unknown amounts of known radiation and to reveal significant amounts of unknown radiation.

The majority of the necessary circuitry has already been incorporated into the basic Analyzer in order to minimize the overall cost of such a system. The principle external accessory to the Analyzer would then be a magnetic storage element such as an endless magnetic tape or a magnetic disc-type recorder. The pulse height analyzer is used to provide the standard samples for the magnetic tape and performs the arithmetic operations required for the subsequent subtraction of these samples from the unknown data.

The Model 34-8 is a completely new approach to the field of multi-channel analysis. This new approach, in conjunction with solid-state techniques—i.e., transistors in place of vacuum tubes, printed circuitry, etc.—allows compactness, low power consumption and heat dissipation and high reliability.

The STANDARD Model 34-8 is capable of operation as either a Multi-Channel Pulse Height Analyzer or a Multi-Channel Scaler (Time Analyzer). There are no extra plug-in modules to purchase in order to perform these separate functions. The change from one analysis mode to another is accomplished by the use of a single toggle switch.

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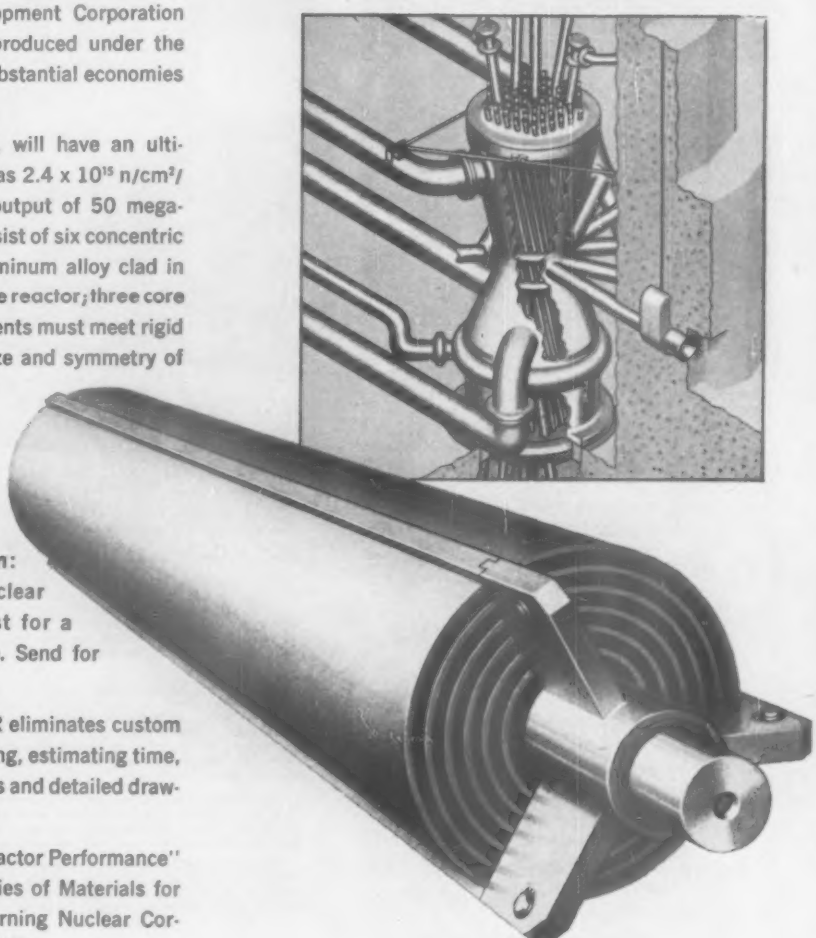

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NUCLEONICS

JEROME D. LUNTZ, *Editor and Publisher*

JANUARY, 1960

The Challenge of the 60's

The United States can have economically competitive nuclear power in the 1960's—if it wants it then. In fact, this goal can probably be achieved closer to the middle of the 60's than to the end—once again, if this is what is wanted.

One would think that the course for this country would be perfectly clear—that we've been pursuing the "competitive power" pot of gold for so long that the pursuit should be relentlessly continued. In fact, NUCLEONICS is of this mind.

However, there have been several seemingly incompatible developments recently that could, in the minds of some, cast a shadow on this:

1. The lessening interest of the USSR and the U. K., the two main atomic competitors of the U. S., in crash civil power programs is said to have reduced one of the main incentives that the U. S. has had.

2. V. S. Emelyanov, Russian counterpart of AEC chairman John McCone, after he completed his tour of the U. S., spoke out against the costly competition in civilian atomic energy between the U. S. and the USSR and called for joint USSR-U. S. research and development efforts in various parts of the field, in particular, fusion, particle accelerators and power reactors.

3. McCone, on his return from Russia, said that although the USSR was not ahead of us he was concerned about their capability of moving quickly towards a goal that they set for themselves. He went on to say it was important for the U. S. to be ahead of the Russians and that to do so we would have to accelerate certain parts of our power reactor program.

Overlying these contradictory views is a clear-cut mandate that emerges from the following:

1. The conclusions of the first phase of the study of AEC's ten-year program, as recently announced by AEC, indicate that a relatively modest expenditure of money ($89-million) in the next five years will bring water-reactor systems to competitiveness just beyond the mid-60's.

2. This view is concurred in by a panel of experts convened by NUCLEONICS (p. 68). In several of the views of this panel, there were seen "great changes within the next five years" with a "real live industry going by 1970."

It seems clear that the U. S. must take on the two challenges it faces: to achieve competitive power in the shortest time, and to cooperate with the USSR in the interests of world peace.

On the first goal—competitive power—whatever money is finally determined to be needed must be sought (indications are that the Joint Committee on Atomic Energy would be quite receptive to such a request), despite Administration tendencies to hold back on such money requests. And the cooperative effort of industry and the AEC should be mounted on short-term reactor concepts to achieve competitive power as close to 1965 as possible. We need no competition from the USSR and the U. K. to make this a desirable goal. It is a vital goal in and of itself.

Adopting this view would then make the course of action with the USSR clear. There is every benefit to the U. S. and to world peace—with no disadvantages—for the U. S. and the USSR to use the atom in the pursuit of peace. The two countries might very profitably combine efforts in the fission power field by working out a joint program on the long-range reactor concepts—breeders, fluid fuel systems, etc.—with the U. S. thus not reducing work on these concepts as proposed by McCone.

This then is the challenge of the 60's: to pursue both these goals—short-term competitive power and collaboration with the USSR on long-term concepts—with great benefit to all concerned.

Outlook for

KENTON LEWIS

SHOUPP LANE COOPER

COHEN DUNWORTH

FOOTE DAVIS SPINRAD

EIGHT DISTINGUISHED VETERANS *of the nuclear industry (see box) recently gathered around a* NUCLEONICS *dinner table to discuss the prospects for nuclear power in the 60's. Of the eight, all but one went on record as saying that during this next decade they expected to see nuclear power plants in operation at competitive costs (at least, in high-fuel-cost regions). The minority of one, Bernard I. Spinrad, felt that the major obstacle to this goal—fuel-fabrication costs—*could be *surmounted by a really concentrated effort but that this effort did not seem to be developing anywhere in U. S. industry.*

The first question, which discussion-moderator (and NUCLEONICS *Editor and Publisher) Jerome Luntz put to each of the panel members in turn, was:*

Do you agree that competitive nuclear power plants will go into operation during the period 1960–1970 in high-fuel-cost areas of the U. S. or in comparable high-cost areas elsewhere?

W. B. LEWIS: "As far as the technical problems are concerned, I think they are easy. We in Canada have to compete with 5-mill power, yet we certainly expect with our D_2O reactor to meet this power-cost level within this period. I think this holds true not only for our reactor, but for other reactors, too, the pressurized-water, the boiling-water, and the gas-cooled—all the reactors on which a great deal of effort has been spent. The most important step toward making these reactors economic will be to get lower fuel costs by increasing neutron economy—a subject I've been preaching for years."

JOHN V. DUNWORTH: "I have little doubt that you will be able to achieve economic nuclear power within this decade in the high-fuel-cost areas of the U. S. We are quite satisfied that we can achieve economic power in Britain in this period."

KARL COHEN: We'll have competitive nuclear plants operating in high-cost areas by 1965 and in medium-cost areas by 1970. I don't think there is any question of this. In fact if anything the goals implied by your question are extremely restrictive. I think we'll have a real live industry going by 1970."

MILTON C. EDLUND: "I tend to agree with Karl. I think the next two or three reactor jobs sold in this country, which will be operating say in 1965 or 1966, will be competitive in the high-cost areas."

JAMES A. LANE: "I'm basically an optimist and I speak from the point of view of someone who is not trying to make money from this business. I, too, go along with Karl. I'm optimistic enough to believe that we'll see

Competitive Nuclear Power

great changes within the next five years and that the present doldrums are purely temporary."

WILLIAM E. SHOUPP: "First of all I would like to ask what you mean by high-cost area? The highest-cost plants are small plants in remote areas which cannot use large plants. Nuclear power will not be competitive for such small plants by 1970. But in those areas which can use large plants, it will certainly be competitive. These nuclear plants will not necessarily be competitive on the first day you start up but will be when you get to fuel equilibrium. Also it might be necessary, in some instances, to average the costs over the plant lifetime of, say, 30 years to show competitive power has been reached.

"But we may have to operate them differently than we do conventional plants. For instance, in some conventional plants built today we generate half of the total lifetime power within the first six years. Since nuclear plants will always be high capital-cost and low-fuel cost plants we will have to operate them on high load factor to compete—which is the natural way to operate high-capital-cost low-fuel-cost plants."

BERNARD I. SPINRAD: "I think we are already in good shape on everything except fuel-cycle costs. Our small prototype plants have already demonstrated that they can fulfill capital-cost requirements successfully in high cost areas. This is not to say that both large and small nuclear plants will not be proportionately more expensive in capital cost than conventional plants, or that technically they will ever be as simple to build and operate as the conventional firebox.

"But I think we tend to defocus from the most important problem—the fuel-cycle costs. No matter how inexpensively we build reactors they will always cost more than conventional plants, at least for the reactors we know about today; hence, if these plants are to compete, the fuel must be cheaper than conventional fuel. We have to achieve fuel costs as low as those quoted by Dr. Lewis, less than 1 mill/kwh or so. Barring a breakthrough, I'm afraid these goals are optimistic. I don't see anything that will lead to costs as low as these within the next ten years. The only hope is a competitive market among fuel-element manufacturers and I don't see this developing."

FRANK G. FOOTE: "In the early 1950's, we started out with the idea that nuclear energy was almost for free. Then the study groups began to calculate and the cost of nuclear energy kept going up and went completely out of sight. I think we are in a period now where it seems to be coming back down and we feel today it is almost competitive with conventional energy. So that today most people are saying that the best we can hope for is to break even with conventional plants. But I think we have to do more than this if we are going to have a flourishing industry—we have to really undercut conventional prices by an appreciable amount. Otherwise where is the incentive to develop a whole new complicated energy source to compete with an already well-established source of energy? Unless we can really undercut the coal plants we are wasting our time. In 1953 I think we had this hope; now in 1959 we don't, but in 1965 I think we may be back to where we were in 1953."

SPINRAD: "May I venture a proposition which I believe in and which I believe I have detected in both the pessimistic and optimistic comments here? I think that the reason for the pessimism that started a year ago and continues up to the present time has arisen because there has been an overselling of the virtues of reactor types and an underselling of the virtues of reactor fuels. In essence we have for a year or two lost sight of what is the fundamental matter in atomic energy—namely, that we have a fuel which at the mine head is extremely inexpensive and that we have to take advantage of this basic fact. What we have done instead of concentrating on or retailing this cheapness of fuel at the mine head is to go hog wild for various private or parochial reactor concepts which use some kind of fuel, but not necessarily a fuel designed explicitly to exploit this fundamental advantage of nuclear energy resources. Forgetting about all other costs in the fuel cycle, fabrication costs alone are so far out of line that

Nuclear-Dinner Guest List

The accompanying exchange of ideas was caught on NUCLEONICS' tape at a dinner-discussion held during the November ANS meetings in Washington. The participating guests, most of whom are shown in action at the left, included: **Karl Cohen**, Manager, Advance Eng., Atomic Power Equipment Depart., General Electric Co.; **John V. Dunworth**, Deputy Director, Winfrith Heath Atomic Energy Establ., United Kingdom Atomic Energy Auth.; **Milton C. Edlund**, Manager, Phys. and Math. Depart., Atomic Energy Div., Babcock & Wilcox Co.; **Frank G. Foote**, Director, Metallurgy Div., Argonne National Lab.; **James A. Lane**, Director's Division, Oak Ridge National Lab.; **W. B. Lewis**, Vice President, Research and Development, Atomic Energy of Canada, Ltd.; **William E. Shoupp**, Technical Director, Atomic Power Depart., Westinghouse Electric Corp.; **Bernard I. Spinrad**, Director, Reactor Eng. Div., Argonne National Lab.

Also present were NUCLEONICS Editors Jerry Luntz, Dan Cooper, John Kenton, Hal Davis and Bob Adamson.

"We have to focus on the problems we have now, not the ones forty years from now."

KARL COHEN
General Electric

"Fuel-fabrication costs alone are so far out of line that unless they come down there is no future in this business."

BERNARD I. SPINRAD
Argonne

unless they come down there is no future in this business. They *must* come down, and by a factor of 2–4."

LEWIS: "I find that Spinrad is so close to my position that I would like to try and resolve any difference once and for all. When I quote prices I am quoting prices outside of the U. S. scheme of things. That is, we have oxides delivered to us by Eldorado which we pass over to private industry in Canada for fabrication. There are only three fuel-fabricating firms. They sinter it into pellets, then we put another contract out to get the pellets assembled into tubes. Now when you go through this operation today, 1959, for the size of tube and pellet and everything else that we are dealing with, the sort of total cost you come out with is somewhere about \$37.5/lb of UO_2. Now we know that what we are paying for here is a lot of small plants of recent capital, who are not sure of future profits, and so on. So we have asked them to give us estimates of future prices, and the figures that we got back ranged from \$20/lb of UO_2 to \$32/lb of UO_2. The figure that I pick is \$24 in 1965 and this in my opinion is not in any way biased."

COHEN: "Spinrad says that fuel fabrication prices must come down, and Dr. Lewis finds that in Canada they are already down. I agree that they will come down, too, so we are all thinking along the same lines. But I must raise a key question—a manufacturer who takes the whole responsibility for the fuel-element as a product and gives a performance warranty is different from the manufacturer who merely works from specifications and lets some other organization like the quasi-governmental Atomic Energy of Canada Ltd. take responsibility. I don't know in detail, but I think perhaps a major part of the discrepancy might lie in this area."

LEWIS: "I think as much as \$5/lb is in fact tied up in this question of product control; we are able to make cheaper fuel not because AECL takes responsibility but rather because of the type of reactor we propose. With our continuous refueling we are not demanding final inspection of each replacement fuel piece. Our inspection on the production line would work with a 5% sample. The reactor itself performs the final inspection. If a fuel piece is offered up to the reactor and, in fact, fails, our fueling scheme is such that the only loss is the loss of the element itself. The fueling machine simply rejects the element with no down-time penalty."

SHOUPP: "We have a large project on what could be a natural-U reactor (the Carolina-Virginia Pressure-Tube Reactor). For this reason we have looked at the relative economics of large-sized reactors of this type in the U. S. compared with slightly enriched reactors of the H_2O type. Generally we are not presently able to show an economic advantage for the natural-U pressure-tube type over the H_2O pot-type reactor. However, I think it is very desirable and a well-recognized principle of the AEC that there are motives other than present-day detailed economic comparisons in developing such reactor types. Fuel reserves and non-dependence on diffusion plants are two reasons."

LEWIS: "We are very interested in seeing anybody get into this business for any reason whatever!"

What do you consider to be the one or two most basic technical problems facing the industry within the next decade?

LEWIS: "I would pick two questions. I will start with the easy one and say that we need reactor materials which can operate at high temperatures but have low neutron absorption. It is unfortunate that the U. S. found such a good high-temperature alloy as Zircaloy-2 because it switched the effort off. There hasn't been a thorough development of another alloy in the whole U. S. effort.

"The other thing is a most difficult thing to speak about, because it is an area which is terribly, terribly sensitive. I would like to put it in a way which appeals to me. In our countries we are concerned, of course, with reducing the number of road accidents, and even the number of railroad crossing accidents. But the amount of money which goes to investigating ways of reducing railroad crossing accidents, which we already have on our hands, is absolutely insignificant compared with the time and money spent today forestalling the most highly improbable types of accidents (things you wouldn't expect to happen to anyone within a hundred years) when we design reactors. This

"We have to get fuel costs below 2 mills/kwh before anything starts to look interesting."

MILTON C. EDLUND
Babcock & Wilcox

"We build experimental reactors—why not build experimental fuel-fabrication plants?"

JOHN V. DUNWORTH
Britain

all comes about only because of the scare in the public mind associated with atomic energy and radioactivity. How are we going to get around this unreasoning fear that people have got—this extraordinarily expensive fear?

"I am in order in speaking about this in a technical conference, because we have, in fact, got the problem with some engineers who find it so terribly easy not to think by taking refuge in codes. In this day and age when we have really mastered the reliability of instrumentation to automatically take refuge in our grandfathers' codes for spring-loaded safety valves, for instance, shows a definite lack of intelligence. I would much rather have a pressure tube which had a safety factor of 20% and which I knew would fail, if it did fail, in a controlled manner rather than one which has supposedly got a safety factor of 4 (as called for by the code), and which people install in such a way that it could blow up in an uncontrolled manner. What we realize this is costing extra money, but how big a problem is it?"

LEWIS: "No, I'm afraid I can't give you an exact figure of this kind, simply because we've had to design our reactors in this conservative manner, but I do realize at many stages along the course, one makes decisions which are not really basically reasonable, but are made merely to conform to some code or other."

FOOTE: "Well, I've just gone through this sort of thing on the fuel for the TREAT reactor. The cost of making the fuel was relatively small, but the cost of health protection, accountability and other nonproductive operations turned out to be two or three times the cost of actually doing the job. Furthermore when we made this material, the health physicists monitoring the operation were unable to detect any activity anywhere—not even in the fuel! And this in my opinion is one of the major reasons why it costs that you can anticipate the problems beforehand. You have all had the experience of designing a plant and finding out after it was built that the *real* problems were vastly different from the ones you spent a lot of time worrying about before.

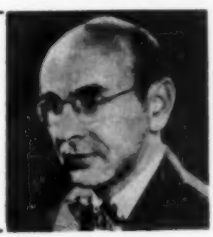
To take a specific example, on the gaseous-diffusion plant at Oak Ridge one of the things we spent the most time worrying about was the time it would take for it to come to equilibrium. Looking back now I don't know why this was of such great interest to us. But we spent two years arguing about it. Again, this is an example of a plant which seemed obviously uninspired; anybody could see that the separation factor was too low. But it turned out that taking this process which was obviously no good and having a small group of people keep their noses to it and make improvements here and there resulted in a major breakthrough, whose full import has not yet been appreciated by most of

"If every reactor we build has a different kind of fuel element, I don't see how we're ever going to get fabrication costs down."

FRANK G. FOOTE
Argonne

"We might well find that overconcentration on short-range approaches has led us up a blind alley."

JAMES A. LANE
Oak Ridge



should be after is to devise design improvements in the sense that the automobile windshield is an improvement over an ordinary flat pane of glass. The pane of glass shatters on impact, but the automobile windshield does not. I am all for safety but not for unreasoning safety—not for blind obedience to grandfather's codes."

SHOUPP: "We have exactly the same problem in the same type of reactor. I couldn't agree with you more."

SPINRAD: "I would have to agree with you, but at the same time I don't think that this is a real killing problem, one that really prevents us from getting economic nuclear power. Although it is a significant one."

EDLUND: "I wonder, Dr. Lewis, if you have made some estimates for your reactor, in terms of dollars per kilowatt, of how much of a penalty you are paying for this excessive safety. We all so much to fabricate things out of uranium."

DUNWORTH: "One of the ideas I would like to see pursued is this. We spent a lot of money on zero-energy experiments for physics studies and on irradiation reactors but anyone who suggested building an experimental plant to manufacture fuel elements that were not immediately needed would be considered absolutely mad.

Yet if we are to assess intelligently what should follow our present pressurized-water, boiling-water and gas-cooled reactors we definitely need realistic fuel costs. At present, fuel element design and fabricating studies seem to follow reactor design instead of being done concurrently."

COHEN: "I think the technical problems for the next five years are to make the things run we are already building, and to find in the course of this what are really the problems. It's very rare the people in this industry. I think the same thing will hold true for power reactors.

To sum up, I would like to come back to my original point and say that the major problem we have today is keeping our attention focused on the problems immediately before us, not the ones 40 years ahead of us, or the ones our grandchildren should be worried about, but the ones that we have with us now."

EDLUND: "I agree entirely that we should focus on the problems at hand. As far as the U. S. is concerned, I think this means we should make every effort to get water reactors competitive within this period. That's all that we really have in this country. If we assume that we have to make 6½-mill power, then what are your problems with water reactors? First of all it's pretty well agreed by everyone that has looked at them that you have to get up to the

"The question is not only whether nuclear plants compete when they start up but whether they compete when integrated over plant lifetime."

WILLIAM E. SHOUPP
Westinghouse

"The most important step in making reactors economic will be to get lower fuel costs by improving neutron economy."

W. B. LEWIS
Canada

size that will go with the largest compound tandem turbine. This means in the range of 300 Mw(e). If we can get capital costs under $225/kw—and I think that there is a fair chance that this can be done—then this means that we have 2 mills/kwh that can be allowed for fuel costs, and this does not even include operating and maintenance costs. You have to get your fuel cost below this 2 mill figure to be competitive and that is what I consider the major problem facing water reactors. Technically, I think this is going to require a lot of fuel-element-fabrication work done by several manufacturers and extensive radiation testing of all kinds."

SPINRAD: "One of the things that we have mentioned already that will help is standardization. But I think this is part of a much larger question. It isn't only the fuel which has to be standardized, and it isn't only standardization per se. But I think the entire nuclear industry suffers from a lack of appreciation of what it costs to make any item just a little differently from the way it is already made.

"From what I have seen we could all of us save considerably more money by adapting our designs to what is already available. I think that we fall in love with our own ingenuity to the point of not realizing that some of our fathers and in some cases our grandfathers were fairly ingenious too and had things down pretty well for a lot of items.

"I've seen specific examples of control-rod designs, for example, that differed just a little from something not quite off the shelf but the next thing to it. But because you've fallen in love with the fact that your rod would fall perhaps 20 μsec sooner, you started the manufacturer all over again redesigning and the next time around you did the same thing. It just seems ridiculous and yet we are doing it every time. In brief what I think this industry needs is a lot less developing!"

SHOUPP: "Another thing I think we need in this country is more small experimental reactors in which you can try things. For instance, if you want to try ways of reducing the max-to-average power ratio or try out some tricky kind of fuel, you can hardly ask the man who has spent $50 to $75 million on his reactor plant to try it out for the first time in his reactor. I think we have a real deficiency of small experimental reactors in which we can try such things out. I don't mean prototype plants or reactor experiments, but rather experimental reactors which will not generate economic power and are not meant to."

LANE: "There are many problems people mention, but a large fraction of them—long fuel life, neutron economy, radiation damage, fabrication and processing costs, etc.—have to do with making *solid-fuel* reactors economic. What's not generally appreciated is that these problems can all be solved at one fell swoop by developing a good fluid-fuel reactor. Contrary to popular belief, the major barrier in the way of fluid-fuel reactors is not the lack of container metals but the lack of ingenuity in designing heat exchangers, pumps and so forth that can be economically maintained or replaced remotely. To me, fluid-fuel reactors appear equally as attractive as solid fuel reactors in getting to lower cost nuclear power. But the trend today is to concentrate all the attention on the short-range reactor types. We might well discover in the next decade that overconcentration on short-range approaches has led us up a blind alley for the very long range outlook."

FOOTE: "We ask whether we will get to 2-mill fuel and I have to say I don't have all the answers. I'm a fuel developer, not a manufacturer, and how these people can manufacture fuels which are so expensive still baffles me. One of the obvious things, however, is that any one of the principal manufacturers, running three shifts, could make all the fuel now needed in the U. S. So you might say that this is a problem which will be solved by courage, confidence and consolidation! And by someone ordering more than a couple dozen fuel elements of one kind.

"I think there is another feature here that is always in the back of everybody's mind. A great number of these costs which we might call auxiliary or secondary costs are relatively independent of the amount of production. If you set up, say, a quality control system to inspect 500 elements a day, pretty much the same system could be used to inspect 5,000 elements a day."

LEWIS: "We've been talking here about the water-cooled reactors. I recognize the problems being discussed, but in Canada we have them to very much less degree—in fact, I can say we've tackled and solved almost all of them. The Nuclear Power Demonstration reactor has 3¼-in. i.d. channels—so has the large reactor. The fuel length we have standardized as being either 1 or 2 units in length for the large reactor and the one unit length for the small reactor. So you can take the fuel right off the production line and, before the large reactor is in operation, feed it as rapidly as you are prepared to afford into the small reactor to see what your production standard, in fact, is before you start operating the large reactor. We haven't got a different kind of fuel for the large reactor than for the small one. There's just more of it.

"As far as the processing of our fuel goes there just isn't any after it comes out of the reactor—we don't reprocess our natural-uranium fuels. People seem to be rather surprised when we say that our fueling cost is going to be no more than 1 mill/kwh but I'm quite sure this is absolutely realistic. This hasn't dropped out of the sky. It's come from paying very careful attention to just the sorts of things we've talked about here."

Rapid Assessment of Neutron Activation

By RUSSELL B. MESLER, *University of Kansas, Lawrence, Kansas*

HERE IS A QUICK and simple method for computing how much activity or how great a specific activity is produced by an exposure to thermal neutrons. It requires only the identities of the product nuclides, reactor flux and exposure time. When more information is available, it can be used with NUCLEONICS Data Sheets 1 and 15 (*1*, *2*) to make other types of computations.

The method is based on an approximation of a true buildup curve by its two straight-line asymptotes and a graphical assessment of the error introduced by the approximation. Figure 1 shows the true buildup curve for a radioactive nuclide produced by thermal-neutron capture $[A = A_\infty(1 - e^{-t/\tau})]$. The two asymptotes (dotted) are (1) a horizontal line at saturated activity A_∞ and (2) a line that represents the buildup of the activity at zero time. In view of the square logarithmic coordinates, the second asymptote is inclined at 45 deg to the horizontal, and the two asymptotes intersect at the mean life of the activity. This is demonstrated later.

Procedure

Figure 2 and the table permit assessment of activities produced in over 100 nuclides. The procedure is as follows:

1. Find the product nuclide with its mean life and saturated specific activity in the table.

2. Use this information to find the intersection point on Fig. 2.

3. From the intersection point draw the appropriate horizontal or 45-deg asymptote to the exposure time and read the corresponding specific activity.

4. Find the ratio of actual specific activity to this approximation from Fig. 1. Apply correction if necessary.

5. Multiply result by ratio of actual thermal-neutron flux to 10^{11} n/cm²/sec.

Saturated specific activities of Fig. 2 and the table are those produced in a thermal flux of 10^{11} n/cm²/sec. This flux is used because this will be about the greatest available in the 10-kw reactor at the University of Kansas. Since saturated activity is proportional to flux, there is no problem in correcting to other flux values (Step 5). The cross sections used are those of the 1958 edition of BNL-325 (*3*). Values are given for nuclides with mean lives between 1 min and 10 years and saturated specific activities greater than 1 μc/gm in a thermal flux of 10^{11} n/cm²/sec. (Figure 2 was prepared with the values from the 1955 edition of BNL-325 and has not been revised. The difference is noticeable only for Ru^{97} and Ge^{75}, and correction can be made easily by the user.)

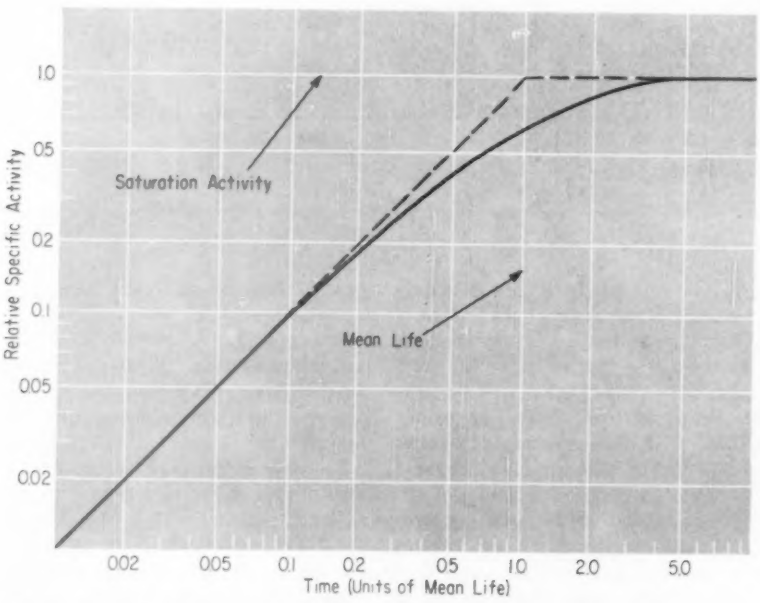


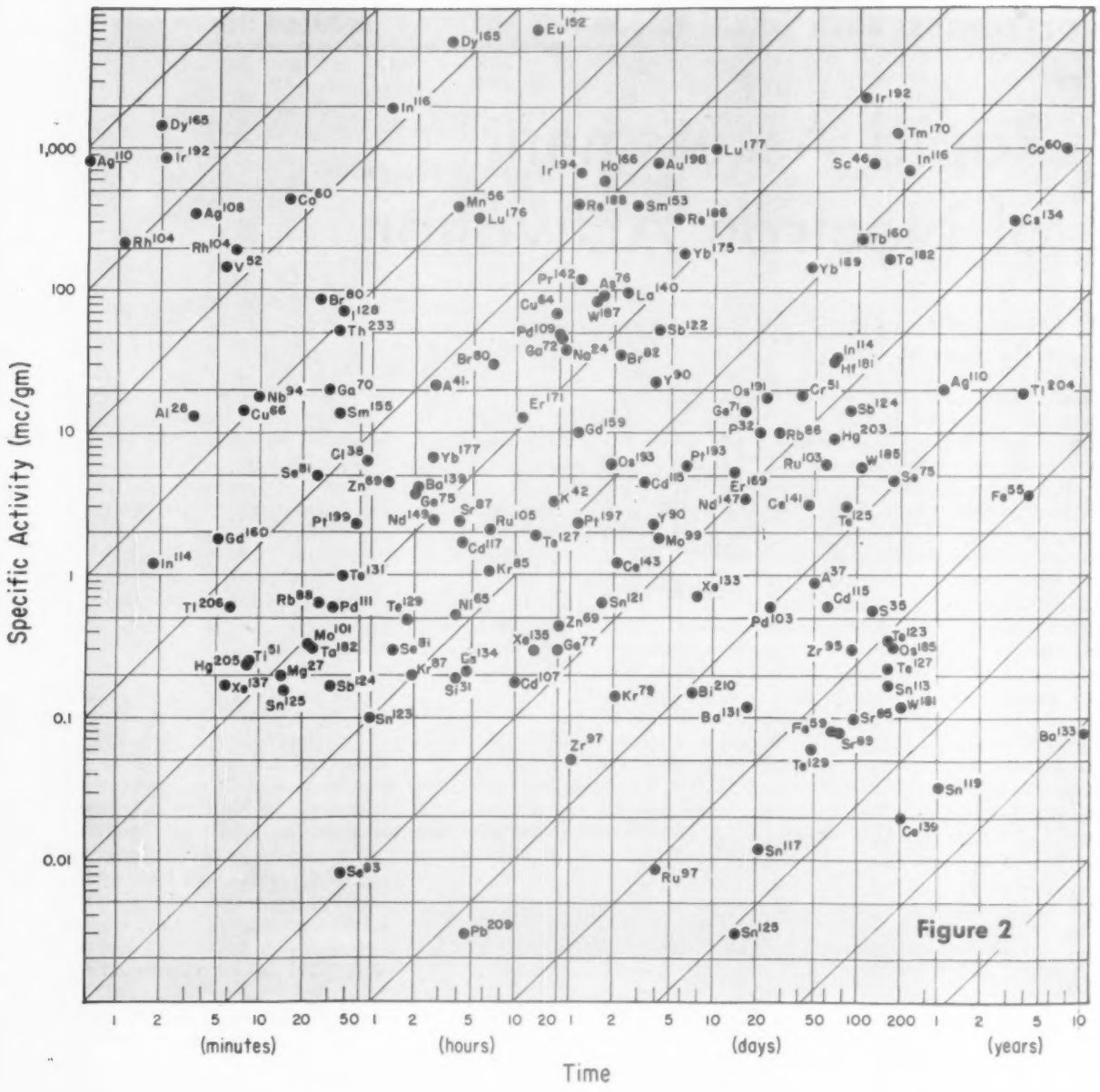
FIG. 1. BUILDUP OF ACTIVATED NUCLIDES in true and approximate versions

Accuracy

The intersecting straight lines give their poorest estimate at an exposure time equal to the mean life of the activity—44% too high. For times less than one tenth of the mean life and greater than three mean lives estimates are within 5%.

To use Fig. 1 for correction (Step 4), one computes the ratio of exposure time to mean life and finds the ratio on the time axis. The correction factor is the ratio of the ordinate of the curve of actual buildup (solid line) to that of the approximation (dotted line).

When Fig. 2 is not extensive enough



for purposes at hand, the points can be replotted on any square log-log graph paper. The cycles of the two scales must be of equal length if the slanting asymptote is to be at 45 deg.

Analysis

To find the equation of the 45-deg asymptote, one expands the factor $1 - e^{-t/\tau}$ in a series and drops all but the first term for times approaching zero. The resulting equation is $A/A_\infty = t/\tau$. When A_∞ is the unit for one axis and τ is the unit for the other, the equation represents a line at 45 deg. Putting $t = \tau$ shows that the line must pass through the point representing saturated specific activity A_∞ and mean life τ. The time axis of Fig. 2 is scaled in minutes, hours, days and years. This eliminates need of making conversions so that exposure time and mean life are in the same units.

For improved accuracy one can compute the correction factor involved in the approximation. For exposure times shorter than mean life it is $(1 - e^{-t/\tau})\tau/t$, and for exposure times greater than mean life the correction factor is $1 - e^{-t/\tau}$.

Example 1. A sample contains 0.05 gm of sodium. What will be the activity due to Na^{24} when the sample is exposed to a thermal-neutron flux of 10^{11} for 1 hr?

Solution: First locate Na^{24} on Fig. 2 with the aid of the table. It is found at 38 mc/gm and 21.7 hr. Follow down a 45-deg line to 1 hr and read 1.5 mc/gm as the specific activity. The activity produced is $0.05 \times 1.5 = 0.075$ mc. Since exposure time is

Mean Lives and Saturated Specific Activities Induced Upon Exposure of Natural Elements to a Thermal-Neutron Flux of 10^{11} n/cm²/sec

Radionuclide	Saturated specific activity (mc/gm)	Mean life	Radionuclide	Saturated specific activity (mc/gm)	Mean life	Radionuclide	Saturated specific activity (mc/gm)	Mean life	Radionuclide	Saturated specific activity (mc/gm)	Mean life
Na^{24}	38.0	21.7 h	Br^{82}	31	2.16 d	Sn^{121}	0.63	1.65 d	Dy^{165}	1,440	1.9 m
Mg^{27}	0.20	13.7 m	Kr^{79}	0.14	2.07 d	Sn^{123}	0.10	58.0 m	Dy^{165}	5,900	3.34 h
Al^{28}	13	3.3 m	Kr^{85}	1.1	6.3 h	Sn^{125}	0.16	14.0 m	Ho^{166}	590	1.64 d
Si^{31}	0.19	3.78 h	Kr^{87}	0.20	1.85 h	Sn^{125}	0.003	14.0 d	Er^{169}	5.3	13.6 d
P^{32}	10.0	20.6 d	Rb^{86}	11.0	28.1 d	Sb^{122}	52	4.0 d	Er^{171}	13	10.8 h
S^{35}	0.56	126 d	Rb^{88}	0.64	25.7 m	Sb^{124}	0.17	30.0 m	Tm^{170}	1,250	186 d
Cl^{38}	6.3	54 m	Sr^{85}	0.10	94 d	Sb^{124}	14	87.0 d	Yb^{169}	145	46 d
A^{37}	0.9	51 d	Sr^{87}	2.4	4.0 h	Te^{123}	0.35	160.0 d	Yb^{175}	180	6.1 d
A^{41}	22	2.62 h	Sr^{89}	0.08	76 d	Te^{125}	3	84.0 d	Yb^{177}	6.6	2.6 h
K^{42}	3.2	18.0 h	Y^{90}	23.1	3.8 d	Te^{127}	0.22	160.0 d	Lu^{176}	320	5.3 h
Sc^{46}	790	123 d	Zr^{95}	0.3	91 d	Te^{127}	1.9	13.4 h	Lu^{177}	1,000	9.8 d
Ti^{51}	0.25	8.4 m	Zr^{97}	0.05	1.02 d	Te^{129}	0.06	48.0 d	Hf^{181}	32	66 d
V^{52}	144	5.43 m	Nb^{94}	18.1	9.5 m	Te^{129}	0.5	1.73 h	Ta^{182}	0.3	23.7 m
Cr^{51}	18.2	40.1 d	Mo^{99}	1.81	4.0 d	Te^{131}	1.00	36.0 m	Ta^{182}	170	160 d
Mn^{56}	400	3.72 h	Mo^{101}	0.33	20.6 m	I^{128}	72	36.0 m	W^{181}	0.12	202 d
Fe^{55}	4.2	4.27 y	Ru^{97}	0.19	4.0 d	Xe^{133}	0.7	7.6 d	W^{185}	5.7	105 d
Fe^{59}	0.087	66 d	Ru^{103}	7.3	59.0 d	Xe^{135}	0.3	13.2 h	W^{187}	85	1.4 d
Co^{60}	1,000	7.62 y	Ru^{105}	2.1	6.5 h	Xe^{137}	0.17	5.6 m	Re^{186}	320	5.5 d
Co^{60}	440	15.0 m	Rh^{104}	190	6.5 m	Cs^{134}	0.21	4.6 h	Re^{188}	410	1.1 d
Ni^{65}	0.52	3.69 h	Rh^{104}	220	1.1 m	Cs^{134}	370	3.3 y	Os^{185}	0.31	140 d
Cu^{64}	76	18.5 h	Pd^{103}	0.59	25.0 d	Ba^{131}	0.12	17.3 d	Os^{191}	18	23 d
Cu^{66}	14	7.42 m	Pd^{109}	41	19.6 h	Ba^{133}	0.08	10.4 y	Os^{193}	6	1.9 d
Zn^{69}	0.45	19.9 h	Pd^{111}	0.6	32.0 m	Ba^{139}	4.2	2.04 y	Ir^{192}	850	2 m
Zn^{69}	4.6	1.25 h	Ag^{108}	350	3.3 m	La^{140}	96	2.4 d	Ir^{192}	2,300	107 d
Ga^{70}	20	29.1 m	Ag^{110}	24	1.07 y	Ce^{139}	0.02	202.0 d	Ir^{194}	675	1.1 d
Ga^{72}	37	20.5 h	Ag^{110}	830	35.0 s	Ce^{141}	3.2	46.0 d	Pt^{193}	5.9	6.2 d
Ge^{71}	18	16.3 d	Cd^{107}	0.18	9.7 h	Ce^{143}	1.22	1.9 d	Pt^{197}	1.7	1.1 d
Ge^{75}	1.7	1.97 h	Cd^{115}	0.59	62.0 d	Pr^{142}	120	1.15 d	Pt^{199}	2.3	45 m
Ge^{77}	0.2	17 h	Cd^{115}	4.6	3.2 d	Nd^{147}	3.5	16.3 d	Au^{198}	790	3.9 d
As^{76}	72	1.62 d	Cd^{117}	1.7	4.2 h	Nd^{149}	2.4	2.6 h	Hg^{203}	9.2	68 d
Se^{75}	4.7	177 d	In^{114}	34	71.0 d	Sm^{153}	400	2.83 d	Hg^{205}	0.24	7.9 m
Se^{81}	5	25 m	In^{114}	1.2	1.73 m	Sm^{155}	13.4	35 m	Tl^{204}	19	3.9 y
Se^{81}	0.3	1.37 h	In^{116}	2,100	1.30 h	Eu^{152}	7,160	13.3 h	Tl^{206}	0.6	6.1 m
Se^{83}	0.008	36 m	Sn^{113}	0.17	162.0 d	Gd^{159}	10	1.08 d	Pb^{209}	0.003	4.6 h
Br^{80}	30	6.6 h	Sn^{117}	0.012	20.9 d	Gd^{161}	1.8	5.2 m	Bi^{210}	0.15	7.2 d
Br^{80}	88	26 m	Sn^{119}	0.033	360.0 d	Tb^{160}	230	105 d	Th^{233}	51.5	33.6 m

only 0.05 mean life, no correction is necessary.

Example 2. Ten grams of nickel alloy containing 10% copper is exposed to a neutron flux of 10^{11} for 1 day. How much activity will be produced?

Solution: The radionuclides produced will be Cu^{64}, Cu^{66} and Ni^{65}. We find each in the table. The last two will be saturated because the exposure time is several mean lives. The Cu^{64} will be exposed for 24/18.5 = 1.3 mean lives. The correction factor from Fig. 1 is 0.7, so that the corrected specific activity is 0.7 × 76 = 53. Thus:

Radioisotope	Activity (mc)
Cu^{64}	53 × 1 = 53
Cu^{66}	14 × 1 = 14
Ni^{65}	0.52 × 9 = 4.7
	Total activity 71.7

Example 3. What neutron flux is necessary to produce in 5 hr 0.1 mc in a 10-gm sample of chromium?

Solution: The desired specific activity is 0.1/10 = 0.01 mc/gm. Locate Cr^{51} at 18.2 mc/gm and 40.1 days on Fig. 2 using the table. Following down a 45-deg line to 5 hr gives a specific activity of 0.09 mc/gm at a flux of 10^{11} n/cm²/sec. Therefore to produce a specific activity of 0.01 mc/gm takes 1/9 of $10^{11} = 1.1 \times 10^{10}$ n/cm²/sec.

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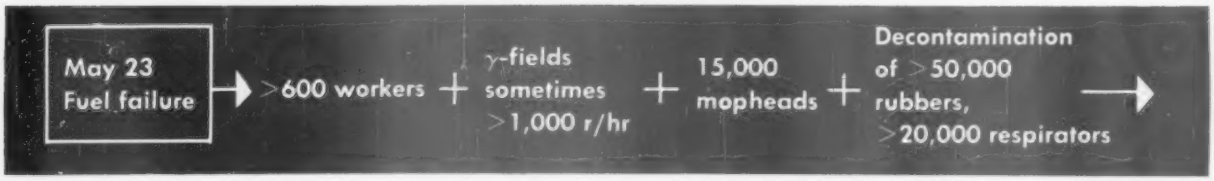
Contamination and Cleanup



By E. O. HUGHES and J. W. GREENWOOD, *Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada*

How Contamination Occurred

On May 23, 1958, an excessive power rate of rise caused an automatic shutdown of the NRU reactor. Alarm signals indicated a number of unusual conditions in the reactor, the most significant being very high radioactivity in the coolant circuit. Other signals were later shown to have resulted from a pressure transient arising from violent failure of a fuel rod.* It was during the efforts to remove this rod and transfer it to the storage pool that the reactor hall became heavily contaminated.

Refueling Procedure

The fuel for the 200-Mw NRU heavy-water research reactor consists of flat plates of natural uranium metal clad with aluminum. Five plates are contained in each of about 200 cylindrical aluminum tubes, which are arranged vertically in the reactor vessel. The reactor is designed for refueling while at full power.

The operation of the fueling flask is illustrated in Fig. 1. In sketch A, the flask is in position over the fuel element. As shown in B, the shielding skirt is lowered and the metal snout of the extendable bellows is sealed to the uncapped hole. The empty flask chamber is filled with heavy water. The valve at the bottom of the flask chamber is opened to create a continuous passage from the reactor to the flask, and the guide tube is driven down around the fuel rod. The guide tube serves to direct coolant into the base of the flask as well as to guide the fuel element. After the rod is raised completely into the flask, it is cooled by heavy water from a built-in circulation system. Another flask chamber is rotated into position to load fresh fuel. The flask then transfers the spent fuel to the storage block.

Refueling Difficulties

In the attempt to raise the damaged element, the guide tube jammed, probably on the buckled fuel. It was decided to remove the plug with the element and guide tube (Fig. 1). To do this, it was necessary to install a larger-diameter bellows and snout.

Preparations for removing the rod were complete on the evening of Saturday, May 24. Contrary to expectations, without the hydrostatic pressure provided by the guide tube, the heavy water drained from the flask; in addition, the rod stuck part way up the flask. At this point, it was impossible to return the overheated rod to the reactor or to apply additional coolant. It is therefore likely that the fuel began to burn in the flask before it was moved to the bridge, where an emergency light-water cooling system was attached. The flask continued to travel toward the storage block, but while it was passing over the maintenance pit, a highly radioactive 3-ft section of rod dropped into the pit and began to burn and set fire to paper and other materials there.

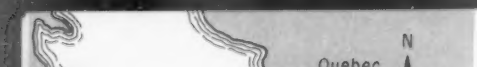
When the flask reached the storage block, the contaminated light-water coolant was permitted to drain into a shaft leading to the storage bay.

At this time, smoke was seen rising from an area around the rod position on the reactor deck. This was later found to have arisen from smoldering uranium or hot uranium oxide that had dropped from the flask while it was still over the reactor. Subsequent investigation showed that a 4-ft section of the damaged rod was lying on the bottom of the reactor vessel.

As soon as the flask had reached the storage block, attention was given to the burning uranium in the maintenance pit. Radiation fields around and over the pit were much higher than 1,000 r/hr (the available monitoring instruments were off-scale) and, behind the shelter of the flask, about 1 r/hr. A team of men carrying buckets of wet sand from outside the building was then sent to bury the burning fuel element in the maintenance pit. Although handicapped by respirators while doing this heavy work, the workers smothered the fire within 15 min of the time the uranium ignited, and the highest exposure received was only 5.3 r.

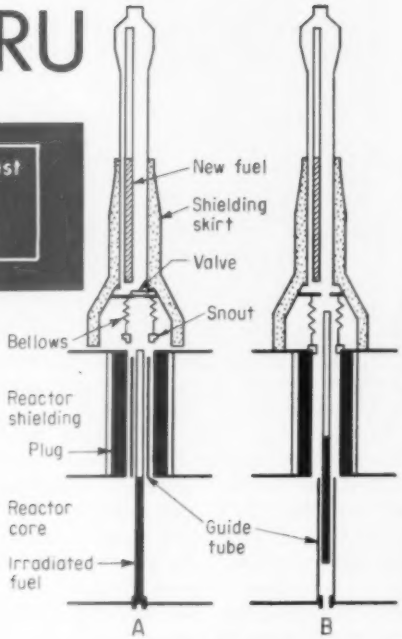
Despite the severity of the failure, it is unlikely that the building would have been contaminated if the rod had been left in the reactor until steps had been taken to guarantee cooling during removal. Several fuel rods, together with the plugs, have since been successfully removed with a special line supplying heavy water to the flask.

* The actual cause of the fuel failure, waterlogging, is discussed in the article beginning on p. 81 of this issue.



# of NRU

End of August
NRU back
in operation



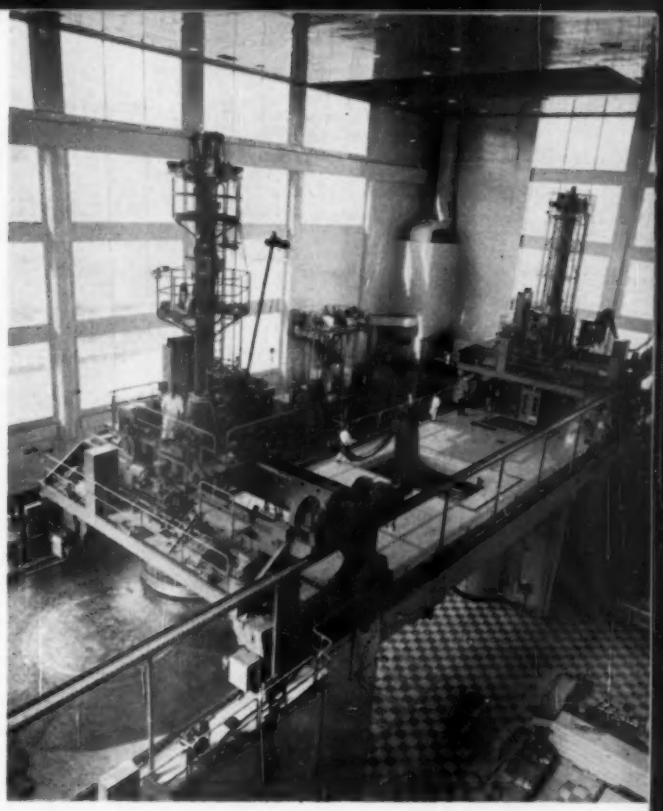


FIG. 1. REACTOR HALL of NRU was scene of major contamination. View shows reactor deck (lower left), bridge to storage block (rear), isotope-removal flask (above reactor) and fueling flask (above storage block); flask-maintenance pit is visible on bridge. Schematic at left indicates operation of fueling flask; with reactor at full power, it removes irradiated fuel and inserts new fuel; plug, occupying tube through reactor shield, contains mechanism for raising and lowering guide tube

Cleanup of NRU and Building

Once the burning fuel fragment in the flask-maintenance pit had been extinguished and the fueling flask had been moved to the storage block, the immediate emergency had been dealt with. The following account of the subsequent cleanup of the reactor hall is not necessarily chronological, although an attempt has been made to achieve a logical sequence.

Removal of Debris

To reduce the high radiation fields, the removal of the burned rod segment from the pit was an urgent requirement. During the night a wooden tray with a metal lip on one side was constructed, filled with sand and lowered into the pit. Then a team of men, working 1 min at a time and using long-handled tools (rakes, hoes and shovels with 24-ft handles), raked the rod segment onto the tray and covered it with sand.

In the meantime, a concrete-block shielding wall had been built around the edges of a semitrailer float to be used in carrying the debris to the disposal area. The driver was shielded by a 4-ft-thick wall at the front end.

Lifting the tray into the maintenance pit and transferring it to the float were difficult. Radiation fields in the cab of the overhead crane used in these operations were 5–10 r/hr, requiring a change of operators every 2 min. In addition, because of the high fields around the tray, the crane operators had to lower it onto the trailer without directions from below.

Preparations to move the trailer to the solid-waste disposal area were completed by the following morning, Sunday. The trailer was then taken to the disposal area, covered with a tarpaulin and left for removal and burial of the debris on the following day.

All the operations described so far were carried out by about 35 men. Despite the fact that they worked near fields of up to and over 1,000 r/hr, the average radiation dose received was only 1.4 r, and the maximum individual exposure was only 6.4 r. This record indicates that extreme care was taken in timing each exposure and that the men concerned took advantage of all available shielding. Nevertheless, it was clear that the cleanup of the building could not be carried out by the NRU staff alone if these men were to remain within the permissible annual radiation limit of 5 r.

On Sunday afternoon, a further attempt was made to reduce the radiation fields emanating from uranium debris and contaminated sand in the maintenance pit. This work was assigned to about 40 men, whose normal work did not involve exposure to radiation, under the direction of an experienced employee who remained shielded by the flask. These men, working in pairs, used long-handled tools to shovel the sand into metal garbage cans and carried the cans to an elevator at the far end of the storage block where they were lowered to the

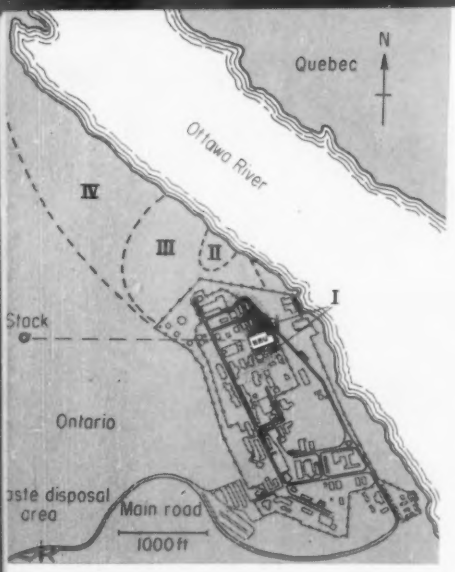


FIG. 2. CONTAMINATION LEVELS of Chalk River project after NRU incident

Zone	Ground survey [cpm above background (~100 cpm)]	Vegetation (dpm/100 mg ash)
I	Up to 20,000	
II	200–800	$\sim 1 \times 10^5$
III	50–200	$\sim 1 \times 10^4$
IV	<50	$\sim 5 \times 10^3$
Other areas	0	$1–3 \times 10^3$

basement. Radiation levels at the can surfaces were up to 200 r/hr.

Prior permission had been obtained for all of these men to receive exposures up to 5 r, but in spite of the 1½-min working time prescribed for each man, 14 of them exceeded the 5-r limit. Of the latter, 11 received 5–6 r (probably by lifting isolated bits of uranium in the sand), two received about 10 r (by slightly overstaying their allotted 1½ min) and one received 19 r (by making an extra trip to the pit edge to bring a can to the elevator). These exposures were the highest received during the entire cleanup.

Contamination, Radiation Levels

Work on the cleanup of the reactor building was now suspended, and the extent of contamination and the levels of radiation were assessed on Monday morning.

Radiation fields as high as 1,000 r/hr were measured 2 ft above the reactor deck and above the maintenance pit. Readings of 100 r/hr at waist level were found in many parts of the main floor. It is not known how much of the fission-product content of the burned uranium became airborne, but the piece of rod that fell into the maintenance pit is estimated to have contained 2×10^5 c of mixed fission products, 700 c of I^{131} and 13 gm of Pu^{239}. The activity on filter-paper smears taken throughout the reactor building was measured with an SU1D survey meter with the end shutter open. The results obtained are shown in Table 1.

Airborne contamination within the reactor hall at the time of the uranium fire was too high to be measured with accuracy. However, readings taken an hour later, 100 yd from the building, were as high as 200,000 dpm/m³. Twelve days after the accident, samples taken in the reactor hall showed that air contamination was still $1–2 \times 10^5$ dpm/m³. Except for unexpectedly low amounts of Ce^{141}, Ce^{144}, Pr^{144}, Ru^{103} and Ru^{106}, the ratio of fission products in the air samples was the same as in the burned uranium.

Contamination outside. While the uranium was burning in the reactor hall, the main exhaust fan in the roof was venting contaminated air directly to the outside atmosphere. The weather was cloudy, with light variable winds. Light rain (less than 0.5 in.) fell on the following day. Although action was taken almost immediately to confine contamination to the reactor hall, light fallout occurred in the vicinity of the building and was detectable 4 days later on vegetation up to 5,000 ft downwind.

The extent and levels of fallout detected on May 27 and 28 are given in Fig. 2. Fortunately, the wind direction was such that contamination of project buildings was negligible except for one or two buildings near the reactor. Air-intake filters of nearly all buildings became slightly contaminated during the night of the accident and were changed a few days later.

Air from the ventilation system of the reactor structure itself is vented through a stack about 3,000 ft from the building. No evidence was found of ground activity as far as 10 stack heights from this structure, indicating that any contamination originating from the reactor proper was effectively held by the filters.

Much more contamination was spread on roads used for transportation of debris from the uranium fire than escaped directly from the building. The roads were cleaned quickly by vacuuming, washing with fire hoses and, when necessary, removing part of the road surface.

TABLE 1—Contamination of Reactor-Building Surfaces*

	Vertical surfaces	Horizontal surfaces (max)
Reactor hall		
Walls		
North, south and east	6–60 mr/hr	450 mr/hr
West	20–400 mr/hr	2.5 r/hr
Floor		100 r/hr (in spots)†
Crane and crane tracks		1 r/hr
Offices, corridors and change rooms	1–2 mr/hr	30 mr/hr

* A reading of 1 mr/hr corresponds to a G-M counter reading of about 10,000 cpm with mixed fission products.

† Measured with a high-range ion-chamber instrument sensitive to beta and gamma radiation.

Cleanup Organization

During the week after the incident, a systematic attack on the decontamination problem was organized.

Since the NRU building was completely contaminated, an emergency headquarters was set up in an adjacent building. From this room, through the use of a remote-controlled television system, it was possible to view nearly all areas in the reactor hall and, through the use of the reactor public-address system, to give instructions to personnel actually engaged in the cleanup. The television system was particularly useful for showing workers

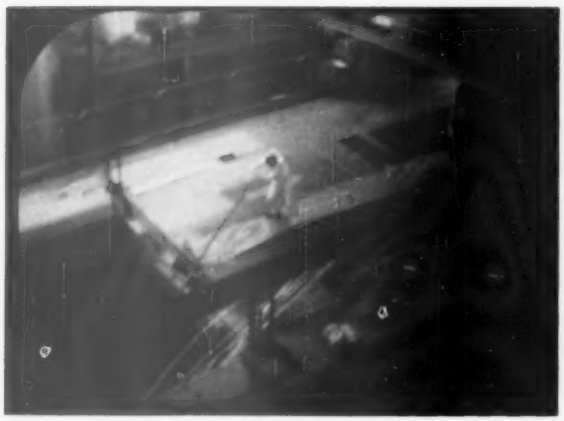


FIG. 3. TELEVISION VIEW of maintenance-pit cleanup. Worker is using long-handled tool

FIG. 4. FLOOR DECONTAMINATION in basement area. Workers wore disposable, one-piece plastic suits

exactly what their duties would be when they entered the reactor hall.

The emergency change rooms (actually the change rooms of the NRX reactor) were located in the same building as the emergency headquarters. Personnel moved between the change rooms and the NRU building through a covered passageway.

Each man employed in the cleanup was provided with protective clothing, a full-face respirator, a film badge and a pocket dosimeter. Dressing and undressing were carefully supervised by experienced personnel. The disposable plastic suits used throughout the operation were developed recently at Chalk River. The wearer's rubber gloves, respirator and rubber overshoes were sealed to the suit with tape.

In the early stages of the cleanup, it was not unusual to find as much as 200-mr/hr surface contamination on used suits. By taking special care to undress the wearer by turning the garment inside out, very few cases of skin contamination were encountered. Since these suits cannot be ventilated, body heat makes them uncomfortable to wear for long periods. Even when radiation levels would have permitted longer work periods, employees were given a 20–30-min rest after 1 or 2 hr of work. Suits were changed during each rest period.

Cleanup of Deck and Pit

In spite of the initial removal of gross debris, radiation levels above the reactor deck and maintenance pit remained extremely high. An early effort was therefore made to remove sand and other contamination from these sites (Fig. 3).

A vacuum system* was used to clean these sites. The nozzle, attached to a long hose, could be manipulated from a distance by long holders. Many problems had to be overcome—for example, the removal of highly radioactive vacuum filters (specially designed flasks were built to receive these), design of a cyclone sand separator to prevent clogging of the filters, and removal of pieces of paper that caused frequent clogging of the vacuum cleaner (long poles with adhesive-coated tips were used for this purpose).

By June 6, radiation fields were reduced to 1 r/hr in most locations, including the neighborhood of the pit. Altogether nearly 300 men took part in this operation, working in carefully timed relays to a maximum exposure of 3 r. The average exposure per man was about 1.5 r (see Table 2 for overall exposure record).

Manpower

At this time, since it was necessary to maintain a reserve of manpower for future operations, normal radiation-exposure limits (300 mr/week) were reimposed for company employees.

At this juncture, the armed forces and civil-defense college came to the rescue and provided about 70 men per day to work three 8-hr shifts for the next 6 weeks. As these men were unlikely to be exposed to radiation in their normal duties, permission was granted to allow total exposures up to 5 r during their work at the project. Actually, only nine of the men received more than 3 r and none exceeded.

By July 7, radiation fields throughout the reactor hall had been greatly reduced and the assistance of armed-forces personnel was no longer required. It was deemed unwise, however, to use inexperienced workers to clean walls, ceilings, overhead crane, etc., in locations up to 90 ft above the floor. For this work, the services of a commercial firm of building cleaners and steeplejacks were obtained.

Decontamination Procedures

Techniques familiar to every housewife were used for decontaminating floors, walls, ceilings and other exposed surfaces (Fig. 4)—wet mopping, wiping with damp rags and vacuum cleaning. The only remarkable feature about this phase of the NRU cleanup was the tremendous quantity of materials required. For example, 15,000 mopheads were used in a 10-week period. All surfaces were washed with a phosphate-based detergent at least three times to reduce contamination to acceptable levels (about 500 cpm). Used rags and mopheads were sent to the waste-disposal area.

Electronic equipment was cleaned by vacuuming and by wiping carefully with a damp cloth. Some instruments could be vacuumed only; the residual contamination was accepted if it was not $>5{,}000$ cpm. Other units were treated at the decontamination center.

Decontamination Center

At the Chalk River project, contaminated equipment from all parts of the plant is sent to the decontamination center. Both manual and me-

* The suction portion of a commercial Vacublast unit.

TABLE 2—Radiation Exposures > 100 mr, May 24–June 29, 1958

	No. of exposures at various dose ranges					
	0.1–0.3 r	0.3–1 r	1–3 r	3–5 r	5–10 r	10–20 r
Company personnel						
Reactor operations	145	17	10	1	3	0
Radiation-hazards control	143	15	2	0	0	0
Maintenance	120	7	7	6	0	0
Other employees*	84	88	39	21	13	3
Off-project personnel	323	112	46	9	0	0

* Not exposed to radiation during normal employment.

chanical methods of decontamination are in use. Among the latter are a large metal-parts washer, an ultrasonic machine and a commercial drum-type laundry machine.

The NRU emergency created an enormous increase in the work load of the decontamination center. For example, about 25,000 rubbers and 10,000 respirators were decontaminated in the month of July. The increase was so great that, during the peak of the cleanup, the decontamination center operated day and night with about three times the normal number of employees.

Fuel Flask and Vessel

The fuel flask was heavily contaminated, and fields of several hundred roentgens per hour were measured around its base. Initial attempts to clean it by wiping, vacuuming and flushing with water and steam were only partially successful. Eventually much of the lower part of the flask was dismantled and decontaminated piece by piece. Although some of the most heavily contaminated parts had to be discarded, the flask was again ready for use by the end of July.

On June 16, visual examination of the interior of the reactor showed that a broken piece of fuel rod and other pieces of debris were lying on the bottom of the vessel. Removal of the broken rod required the construction of a special tool to raise the segment into a vertical position and to lower it into a container inside the reactor vessel. The container was then lifted into a shielded flask and taken to the rod-storage bays.

Other rod fragments were picked up with mechanical fingers. However, for the smallest pieces, ranging in size down to grains of uranium, a special technique had to be devised. After preliminary tests had shown that these pieces would adhere to plasticine under water, a cylindrical tool was made from which plasticine could be extruded and then sliced off after it had picked up a load of debris. Except for modifications not related to the emergency, the reactor could have operated in the first week of August.

Internal Contamination

During the first night of the emergency, protection against internal contamination was not as effective as it was in the later stages. Men present while the uranium was burning were dressed in white coveralls and were wearing modified "comfo" dust masks, which cover the mouth and nose. Those who carried sand to extinguish the fire were using Canadian Army combat respirators, which contain pleated filter paper to stop particles and activated charcoal to absorb gases.

Some cases of internal contamination were traced to improper use of respirators—for example, raising the facepiece briefly to breathe more easily or to speak to another worker (all respirators have since been fitted with speech diaphragms). Other cases resulted from the relative ineffectiveness of the dust masks against iodine. Nevertheless, the over-all control of internal contamination was highly effective.

About 2,000 24-hr samples of urine were tested for radioactivity between May 24 and July 31. (Respirators were not required in the reactor hall after July 21.) Of these, less than 10% were positive for mixed fission products or iodine, and subsequent calculations showed that no one had received an overexposure to radiation as a result of internal contamination. Cesium-137 levels in the urine were no higher than those then present as a result of weapon fallout. Tests for Pu^{239} and tritium were negative.*

Lessons Learned

Chalk River has experienced two major incidents of contamination of reactor buildings, NRX in 1952 and NRU in 1958. The decontamination of the NRU building could not have proceeded so effectively if the NRX experience had not led to the sealing of all vertical and horizontal surfaces in NRU with smooth finishes, which were easy to decontaminate. In addition, the NRX incident led directly to the construction of a change room that would be readily accessible from NRU.

In the NRU cleanup, it was fortunate that the NRX facilities were close at hand. Nevertheless this led to some inconvenience for the NRX staff. In future incidents, use will be made of a mobile change room, which can be brought to the exit of any affected building.

The use of wet sand to smother the uranium fire was a necessary improvisation; graphite powder would have been better. Graphite supplies are now available in areas where such incidents might occur. The use of rags and mops, while effective, was extremely time-consuming. We are investigating mechanized cleaning methods. Other devices now in the development stage are portable remote-controlled radiation monitors and portable shielding walls, which can be installed with minimum radiation-exposure time. Also under study is the possibility of shielding the cab of the overhead crane or of operating the crane by remote control.

FOR FURTHER DETAILS SEE

1. W. Boyd, F. W. Gilbert, G. C. Laurence, I. M. Mackay. The NRU reactor, in "Second International Conference on the Peaceful Uses of Atomic Energy," vol. 10, p. 128 (United Nations, Geneva, 1958)
2. J. W. Greenwood. Contamination of the NRU reactor in May, 1958, CRR-836 (1959)
3. I. L. Ophel, W. F. Merritt. Radioactive contamination of the project outer area following the NRU fuel rod incident of May 24, 1958, CRER-815 (in manuscript)
4. G. W. C. Tait, T. H. Byington. Respirator problems in atomic energy practice, *Am. Ind. Hyg. Assoc. Quart.* **19**, 123 (1958)
5. J. M. White. Health physics problems following a reactor accident, *Am. Ind. Hyg. Assoc. Quart.* (in press)

* The analytical procedures used would have detected 1×10^{-10} μc/ml of Pu^{239} and 1 μc/l of tritium.

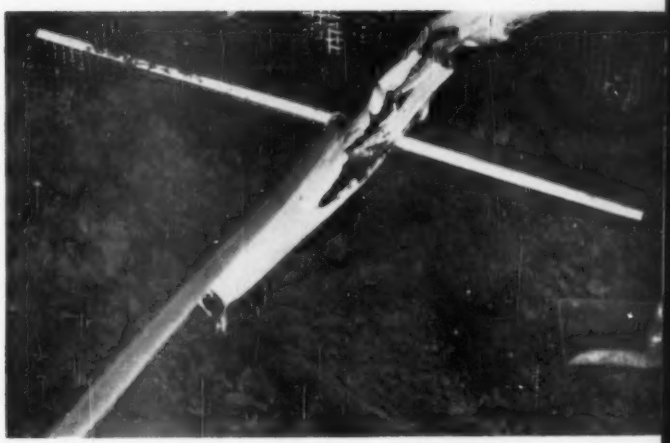


FIG. 1. FUEL TUBE damaged in NRU incident of May, 1958. Although distorted during disposal, rupture is evident. Waterlogging and bursting at startup are believed cause

Chalk River Experience with Fuel Waterlogging

By A. J. MOORADIAN, G. M. ALLISON and J. F. PALMER, *Atomic Energy of Canada Ltd., Chalk River, Ontario, Canada*

Water accumulation within fuel cladding coupled with thermal cycling can lead to bulging and failure of cladding—apparently the cause of the NRU failure

THE MAY, 1958, FUEL FAILURE and subsequent contamination of NRU dramatically emphasized a problem of importance to water-cooled reactors—waterlogging of the fuel.

Any fuel element in which water has accumulated within the cladding is considered waterlogged. Prerequisite conditions are a defect penetrating the cladding and a void within the cladding. In fuel elements operating at a high specific power, large quantities of water cannot accumulate within the void while the reactor is in operation—any water entering that does not react chemically is turned to steam. Waterlogging can develop only when the power is lowered or the reactor is shut down. Therefore, the effects of waterlogging are most apparent on reactor startup. Failure of the element can then follow through generation of steam within the void with or without accompanying reaction of the water with the fuel-core material.

Aside from fuel damage, waterlogging has an advantageous aspect. The accumulation of water in a void followed by steam generation leads to an increase of fission-product activity in the reactor coolant. With a suitable monitoring system, a fuel defect can be detected and localized.

This discussion is limited to two fuel types with which Chalk River has had waterlogging experience—aluminum-clad uranium metal (NRU type), in which the chemical reaction can occur, and Zircaloy-clad uranium dioxide, in which damage is restricted to steam pressure. Methods are also discussed for detecting and localizing fuel defects involving waterlogging.

NRU-TYPE FUEL

Figure 1 shows a section of the ruptured tube of the NRU fuel element that failed on May 23, 1958 (*1*). Before that incident, 14 NRU rods failed—all nonbonded fuel (Fig. 2 shows a typical failure). Examination indicated two basic causes: (1) leakage of the closure welds and (2) the nonbonded nature of the fuel.

A contributing factor in the fuel failure of May, 1958, is believed to have been the restriction of coolant flow in the fuel rod. Experience has shown that this can occur by one of two mechanisms—bulging or wrinkling of the cladding. Wrinkling (Fig. 3) appears to result from differential thermal expansion of the uranium core and the cladding, which causes ratcheting and an accumulation of metal in the wrinkles. Bulging, on the other hand, is apparently due to leakage of water into the fuel; since this is a discussion of waterlogging, bulging will be discussed further.

Bulging

Five of the NRU rod failures before the incident of May 23 involved bulging. It usually extended for several feet and was confined to one side of the flat.

A possible explanation is that, when a bulge forms, the opposite surface of the flat must take up the heat load. In so doing, the nonbonded interface can become sufficiently hot (400° C) to induce bonding by interaction of

uranium and aluminum. In support of this theory, in some cases the surface opposite the bulge had a finely pimpled appearance—similar to the condition produced by heating a fuel plate above 400° C and characteristic of the formation of UAl_3 at the sheath-to-core interface.

Internal pressure can be created by boiling water on reactor start-up. However, in fuel elements susceptible to corrosion, such as we have in NRU, this is complicated by possible chemical reactions of water or steam with uranium and its corrosion products.

A number of out-pile experiments have been conducted on sections of weakly bonded extrusion-clad plates to study the bulging mechanism (*2*). The results are directly applicable to nonbonded flats. The experimental setup is shown in Fig. 4. A fuel-element section is clamped between electrical contacts and is heated by passing current. A defect in the sheath, 0.013 in. in diameter, is exposed to water at a pressure 1 to 2 psi above atmospheric. The fuel element is thermally cycled by holding it at 300° F for 8 hr and then at room temperature for 16 hr. Normally, it requires two cycles to form blisters, after which growth is relatively rapid. Even with 0.025-in. cladding, the sheath can become almost cylindrical without rupturing.

In one test, a bulge was formed and punctured, and a pressure gage was brazed to the sheath. On cycling, the following events took place: (1) at 200° F, the gage read 1 psi; (2) as the temperature increased to 260° F over an interval of 30 sec, the pressure rose uniformly to about 18 psi; (3) thereafter, the pressure increased rapidly to 62 psi, the temperature remaining at 260° F (saturation pressure for steam at this temperature is 21 psi). The pressure increase from 18 to 62 psi required a fraction of a second, and it was during this interval that the bulge growth took place. At this point, the heating current was switched off; it required about 30 min for the element to cool to room temperature, at which time the pressure was still 35 psi. After 16 hr, the gage gave a negative reading.

In further tests, similar induction temperatures were recorded for blister growth. In one case, the pressure increased to 100 psi, and in another the pressure increased very rapidly until the sheath burst (Fig. 4). The gas in the bulges was hydrogen.

These observations cannot be explained by the simple reaction of water or steam with bulk uranium metal since oxidation is too slow at these temperatures to account for the fast evolution of gas. Our hypothesis is as follows:

A defect introduces water into the sheath. The water reacts with the bulk uranium to give UO_2 and hydrogen. The speed of the reaction is temperature-dependent, but the reaction can occur under prolonged shutdown conditions at a small defect. The hydrogen subsequently forms uranium hydride. On the next cycle, more water is introduced. There are then two competing reactions—water with bulk uranium and water with uranium hydride. However, uranium

FIG. 2. TYPICAL FAILURE of NRU nonbonded fuel before May, 1958, incident

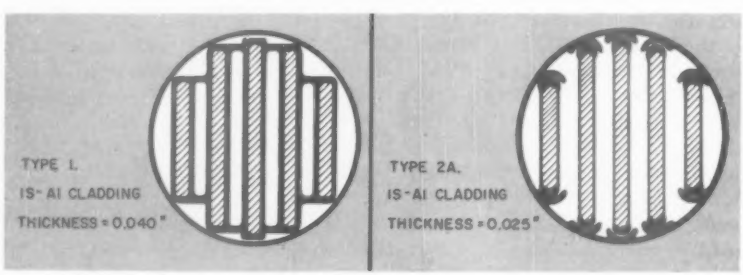
NRU Fuel Design

Because of the high power density of NRU (*3*), the fuel had to have a high surface-to-volume ratio. It was first designed as a cluster of five parallel flat plates of uranium metal, 10 ft in length, clad in 1S aluminum.

Three designs have been developed: (1) an element with no bond between sheath and core (type 1); (2) a weakly bonded element, 4,000 psi bond strength (type 2A); (3) the well-bonded element, 6,000 psi bond strength (type 2A).

The nonbonded elements are made by fabricating separately the uranium core and the aluminum sheath. The two are then assembled with aluminum end tabs, and the whole is drawn through a die which sinks the sheath onto the core. End closures are made by hand welding.

The bonded elements are made by the process of extrusion cladding (4).



For the weakly bonded elements, aluminum is extruded directly onto bare uranium. For the well-bonded elements, the uranium cores are first nickel-plated. Discussion in this article is confined to the nonbonded and weakly bonded elements since these are the types most susceptible to waterlogging.

On the basis of experience with NRX (*5*), it was decided to use nonbonded plates for the first charge of fuel for NRU. However, in the United States, considerable importance was being given to the secure bonding of flat-plate elements. As insurance against any unsatisfactory performance of nonbonded flats, the development of the extrusion cladding process was undertaken in Canada.

The first fuel loading for NRU was 202 rods. Of these, 190 were nonbonded flats and the remaining 12 weakly bonded extrusion-clad plates.

FIG. 3. WRINKLING of Al-clad fuel plate caused by thermal expansion

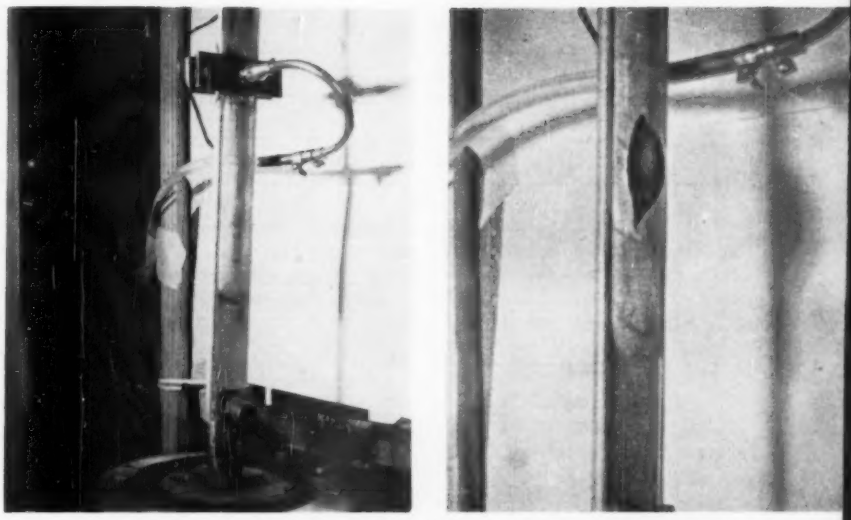


FIG. 4. BULGING OF CLADDING is waterlogging effect. In tests, plates were electrically heated; at left, pencil marks indicate successive thermal cycles; at right, bulge burst

hydride reacts very much more quickly and causes a further evolution of hydrogen. Thus, more uranium hydride is formed. This sequence continues with each temperature cycle until hydrogen pressure is sufficient to rupture the sheath.

To test this hypothesis, a second experiment was carried out. Uranium hydride was first formed under the cladding by treating the defect with hydrogen gas. On subsequent waterlogging at room temperature, no reaction took place. As the waterlogged fuel plate was brought up to temperature, it bulged rapidly at a temperature similar to that encountered in the previous experiments.

May, 1958, Failure

The out-pile tests just discussed throw some light on the explosion of the nonbonded fuel rod that occurred in the reactor in May, 1958. Although the mode of failure cannot be conclusively proved, one of the most attractive hypotheses is as follows:

By the mechanisms described previously, one of the flats in the rod had bulged and a considerable amount of uranium hydride had been formed before the incident of May 23. While the reactor was shut down, serious waterlogging took place, resulting in an explosion on startup. There is an indication that the explosion caused a pressure pulse lasting 1–2 sec (*6*). Had it been purely a steam explosion, it is doubtful whether the pressure would have been sustained for so long—the steam must have been mixed with a noncondensable gas, such as deuterium. The situation is thought to have been aggravated by a restriction of the coolant flow by both bulging and wrinkling of the flats.

The lack of a warning signal by the activity monitors before the May 23 incident can perhaps be understood by studying the history of previous failures. Some of the elements had failed at the bottom closure weld, but blisters appeared midway up or near the top of the fuel length. This effect can be reproduced in out-pile tests on bottom-defected elements under NRU flow conditions. It seems that the nonbonded sheath of an NRU fuel element is sufficiently weak to be deformed easily under the high pressure gradients caused by the flow of coolant up the fuel rod—in the most highly rated rods, the gradient is 50 psi over a 10-ft length. But a pressure differential of only 1 psi can cause a sheath deflection of about 0.001 in. Thus, at every point up the fuel element except the last few inches, one would expect water to leak in through a defect rather than fission products to leak out. Unless the defect occurs at the extreme low end of the coolant-pressure gradient, there would be no fission-product-gas signal.

ZIRCALOY-CLAD UO_2

The fuel for Canada's first nuclear-power reactor, NPD-2, is to be sintered UO_2 pellets stacked in cylindrical Zircaloy-2 tubes, allowing a limited diametral clearance between the fuel and the tube.

In high-temperature, high-pressure water, a fuel element of this type with a small defect hole through the sheath, it has been postulated (*7*), will have hydrogen and steam in the gap between the fuel and the sheath. If the reactor is stopped or its power reduced to a low level, the fuel will cool rapidly and water will be drawn in through the hole. When the reactor power is subsequently raised, the fuel temperature will increase and steam will be forced out of the element through the defect.

Eichenberg et al. (*7*) have presented three possible mechanisms of waterlogging failure in UO_2 fuels: Water trapped within a defective fuel element during shutdown would produce steam on startup at sufficiently high pressures to expand or even rupture the sheath (1) if the steam cannot escape fast enough through the defect hole to relieve the pressure, (2) if the defect hole has become blocked with a piece of thermally fractured UO_2 or (3) if the water has permeated connecting pores in the oxide and then fractured it violently upon boiling.

Mechanism 1 depends on the clearance between fuel and sheath and the size of the defect hole, whereas mechanism 3 depends on the amount of open porosity in the UO_2. Blocking of the defect hole was observed in the

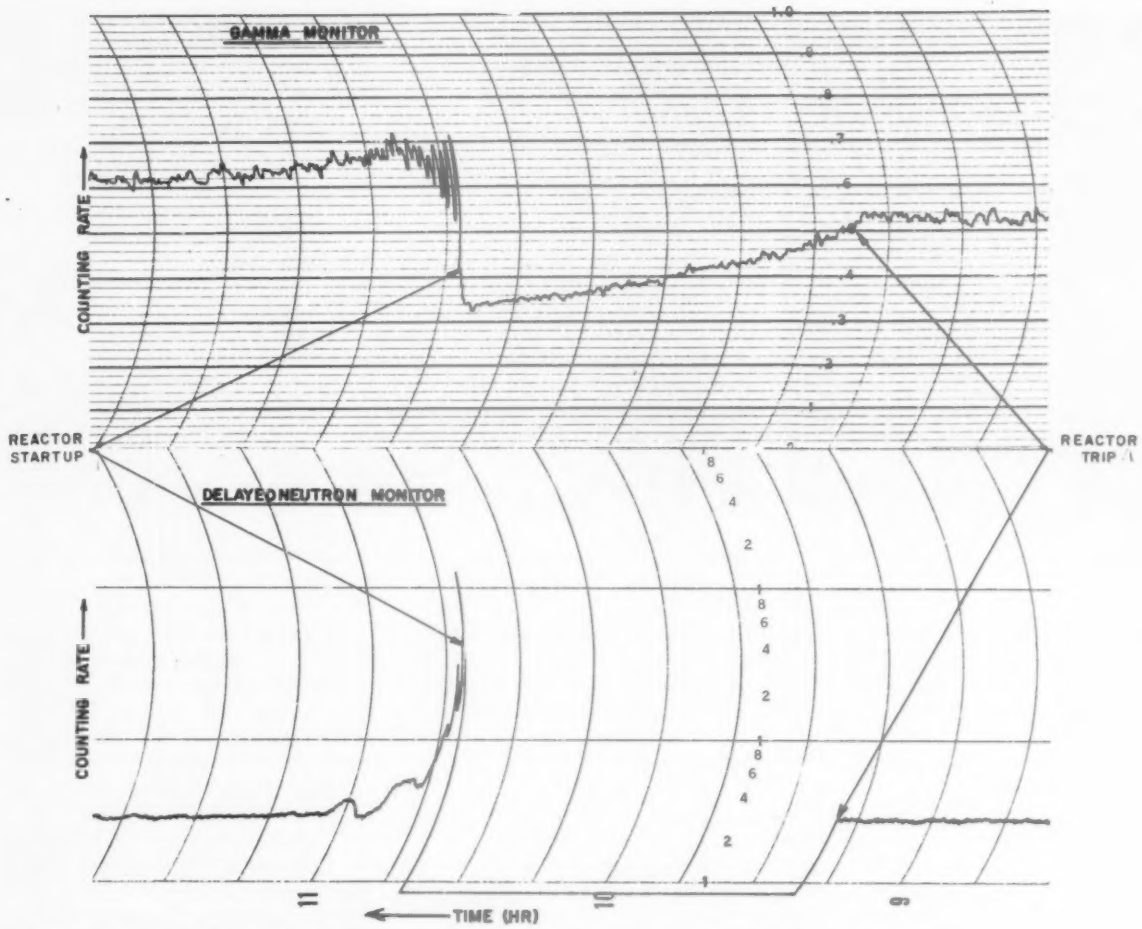


FIG. 5. MONITORING RECORDS of NRX loop tests show startup peaks resulting from waterlogged fuel elements

ninth PWR fuel test (X-1-L), which operated in NRX for 1 year with a defected UO_2 element (*8*). Monitor behavior and radiochemical analysis indicated that the defect hole was blocked several times during the tests. However, this blocking occurred during steady reactor operation. A shutdown and startup always cleared the defect hole with no damage to the specimen.

Up to May, 1959, we conducted at Chalk River more than 30 loop tests in which the fuel charge was made up of numbers of rod-type UO_2 specimens. Only two failures attributable to waterlogging occurred:

1. A defected element failed during the first PWR fuel test (X-1-b) in the NRX reactor (*9*). The cladding bulged and split at the bulge. The UO_2 in this test was low-density material (~80% of theoretical density), and the failure was attributed to water permeating the connecting pores of the oxide and fracturing it on boiling (*7*).

2. The ninth fuel charge irradiated in the EEC loop in NRX (this loop is used by AERE, Harwell) consisted of specimens of high-density stoichiometric and nonstoichiometric UO_2 clad in stainless steel. Although none of the specimens was supposedly defected, monitors indicated on initial reactor startup that a small defect was present in at least one element. A subsequent reactor trip and startup caused a burst of activity, which necessitated removal of the fuel. One of the nonstoichiometric UO_2 specimens (O/U = 2.15) was found to have a 0.010-in. bulge near the middle and a crack at the bulge (*10*). This failure was attributed to small cracks on the inside of the cladding, one of which penetrated the sheath wall during preirradiation testing and subsequently enlarged under stresses during irradiation.

In spite of the obvious possibility of failure from waterlogging when defective nonbonded UO_2 is irradiated in high-temperature, high-pressure water, the experience obtained in loops indicates that such irradiations can continue for long periods without failure and without excessive fission-product activity in the coolant.

DETECTING FUEL DEFECTS

An important factor in NRU fuel-failure experience before the May, 1958, failure was the unreliability of the system for detecting incipient failures, such as bulging and wrinkling. In every case, a distinct rupture of the

cladding was necessary before the failure could be clearly detected. Admittedly, the sensitivity of the activity monitors had been decreased by the uranium contamination of the NRU recirculating-coolant system, which had been high since startup.

The detection of an increase in activity in the primary coolant is not difficult using gaseous-fission-product monitors as in NRU (*11*). Methods of detecting volatile halogen fission products (*12*), predominantly I^{135}, have been used satisfactorily in loop experiments at Chalk River. Both these methods are particularly suitable for detecting long-lived volatile fission products.

However, locating the failed element is a more difficult problem, especially in reactors with a recirculating cooling system. The difficulty is further increased if the long-lived fission products are released gradually so that the activity in all channels increases at about the same rate. It is here that advantage can be taken of waterlogging.

Recoil atoms coming from the area of fuel exposed by an opening in the sheath will increase the short-lived activity in the coolant. For a small hole, this increase is insignificant. If, now, the reactor power is dropped, waterlogging takes place. When the reactor power is again increased, steam is forced out of the defect hole, carrying fission products with it. The short-lived fission products added to the coolant result in a transient peak on a monitor sensitive to short-lived nuclides, e.g., a delayed-neutron (DN) monitor (*13*) detecting neutrons from I^{137} (22-sec half-life) and Br^{87} (56-sec half-life).

Defect tests on UO_2 fuel elements in NRX loops have repeatedly demonstrated the advantage of the DN monitor over monitors designed to measure long-lived fission-product activity. In Fig. 5, startup peaks are shown for two monitors, DN and gamma, in an NRX loop test. (The gamma monitor is a G-M tube placed against a section of loop piping and shielded with lead.) In this test, a UO_2 fuel element was defected with a 0.005-in.-diameter hole through the Zircaloy cladding. The monitor records in Fig. 6 show on reactor startup a DN peak 40 times background, whereas the gamma activity shows an increase only 1.5 times background level. Tunnicliffe (*14*) has examined the monitor records from several UO_2 defect tests in NRX loops and has found that the DN peaks on reactor startups are generally 3 to 100 times the average level during steady reactor operation; in one test they were as high as 1,000 times average. The gamma peaks on reactor startup are generally 1.5–5 times average.

It should be noted that most UO_2 fuel failures in Chalk River loops have caused large transient increases in long-lived activity. These have been readily detected by iodine and gross-gamma monitors. Failures giving a gradual increase of long-lived activity are rare.

On the basis of this experience, NPD-2 has been designed with activity monitors sensitive to long-lived fission products for the detection and location of defective fuel elements. In the case of a gradually increasing monitor signal, the failed element can be located by taking advantage of waterlogging to produce a slight transient increase of long-lived activity on cycling the reactor power.

CONCLUSIONS

At this early stage, it is perhaps naive to assume that consistently perfect fuel can be fabricated. If it is accepted that fuel defects are likely, than we must find criteria that will minimize the hazards of waterlogging without impairing the facility with which minor fuel defects can be identified and located. In developing these criteria, we must consider the fuel-element design and the reactor startup rate.

Fuel Design

It is desirable to have as rigid a cladding as is consistent with neutron economy. The Chalk River experience with nonbonded NRU fuel stresses the importance of having a fuel sheath that will not deform in response to small pressure gradients. For a given material, the rigidity depends on shape and thickness. A sphere would be the best shape, but, as a practical compromise, Chalk River has chosen for the present a solid cylindrical fuel element.

The total void space (and its disposition in the fuel element) also influences the amount of water that can enter the sheath. The smaller the total volume of the water and the closer it is to the defect, the less chance that the sheath will deform on reactor startup. Thus, short elements are favored.

Startup

Chalk River experience indicates that, if a defective fuel element can survive reactor startup, it can be operated for long periods without seriously contaminating the coolant system. It is generally accepted that the hazard of fuel damage through waterlogging increases with the rate of startup. If the startup rate is sufficiently conservative, there is a good possibility that unscheduled shutdowns for removing defective fuel can be avoided, but no serious study has yet been made to optimize the startup rate in the economy of reactor operation.

Our present position at Chalk River is that the waterlogging problem has just recently become clearly defined. An experimental program is being planned to investigate the effect of startup rate. Probable sizes of defects, duration and conditions of shutdown, and size and disposition of void space are all factors that will have to be considered.

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HTGR—Underlying Principles

Highly dispersed fuel in an all-graphite core and continuous fission-product removal are among the advanced design features that will help the HTGR produce 1,400° F helium at high power densities

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THE ULTIMATE GOAL in developing the High-temperature, Gas-cooled Graphite-moderated Reactor (HTGR) is to combine in one reactor the high-temperature potentialities of gas cooling with high power density and a fuel capable of high burnup. We believe that the proposed concept—a helium-cooled, solid-homogeneous type of reactor, in which carbides of fuel and fertile material are dispersed in graphite—offers the best prospects of realizing these objectives.

This is not the first time that this general approach has been advocated—as long ago as 1946, Daniels* proposed a semihomogeneous gas-cooled reactor; more recently, the British DRAGON project† has advanced these ideas to the point of providing a practical basis for the construction of a small, high-temperature reactor experiment. The HTGR prototype proposed by General Atomic would go a step further and demonstrate the potential of this class of reactor as a practical economic power producer.

Since the HTGR prototype is substantially different in approach from other power reactors presently being operated or constructed, it is perhaps desirable to discuss first the ideas underlying the concept and our reasons for interest in them. We will start with some of the thermodynamic considerations; in particular, how it is possible to avoid the low power densities associated with natural-uranium, gas-cooled systems and how high gas temperatures can be utilized to effect substantial reductions in plant costs.

Heat Transfer

The problem of applying gas cooling to reactors that use enriched uranium fuel is very different from applying it to reactors fueled with natural uranium. Essentially, the problem of natural-uranium graphite-moderated reactors is to avoid the loss of too many neutrons in the U^{238}; this means, in practice, that fuel elements have a low surface-to-volume ratio (round rods) and are pitched in a relatively widely spaced lattice. As a consequence, the amount of fuel-surface area that can be accommodated in a given core volume is greatly restricted, and extended surfaces (fins) must be used on the fuel elements to obtain acceptable heat transfer unless one goes to very high coolant pressures and pumping powers. Unfortunately,

* C. Rogers McCullough, *et al.*, Summary report on design and development of high temperature gas-cooled power pile, MonN-383, September 15, 1947.

† L. R. Shepherd, R. A. U. Huddle, L. A. Husain, G. E. Lockett, F. Sterry, D. V. Wordsworth, The possibilities of achieving high temperatures in a gas reactor, Second United Nations International Conference on the Peaceful Uses of Atomic Energy, P/314.

Technical Data for High-Temperature Gas-Cooled Reactor

Operating Conditions		Core diameter (ft)	9.0
Coolant	Helium	Core length (ft)	7.5
Pressure (atm)	20	Core coolant voidage (%)	12.8
Inlet temperature (° F)	660	Fuel-element diameter (in.)	3.50
Outlet temperature (° F)	1,380	Number of fuel elements (approx.)	810
Maximum fuel-surface temperature (approx.) (° F)	2,300	Reflector thickness (ft)	2
Steam temperature (° F)	1,000	Core graphite weight (metric tons)	19.5
Steam pressure (psia)	1,450	Reflector graphite weight (metric tons)	47.7
Net thermal efficiency (%)	34.8	Pressure-vessel diameter (inside) (ft)	14
Reactor thermal output (Mw)	115	Pressure-vessel height (ft)	34
Net electrical power (Mw)	40	Core graphite/uranium ratio	1,900
		Burn up	
Reactor Parameters		Fissions per original fissile atom	0.63
Fissile investment (kg U^{235})	190	Mwd(th) per metric ton of $U^{235} + Th^{232}$	80,900
Thorium investment (metric tons)	1.19	Core life at 80% load factor (yr)	3

and Design

the high-temperature materials that are available are not suitable for fins. In fact, it seems clear that for both high outlet temperatures and high power densities, finned surfaces are not very beneficial—one must go to configurations that increase the base fuel surface per unit core volume and this means enriched fuel.

In enriched systems, a first step toward lessening the cooling problem might be to use either thin plates or assemblies of small-diameter rods as fuel elements. Although either method obviously increases cooling surface, both are attended by serious mechanical difficulties, particularly the maintenance of fuel-element structural stability under prolonged irradiation. Furthermore, this solution is one of strictly limited scope; just to break even on effective cooling surface area without the use of fins requires fuel elements that have considerable complexity, which limits their practicability.

However, an alternative way of increasing effective core heat-transfer surface—without resorting to multitudes of small parts—is to include the moderator within the fuel elements. In this way, a very large cooling surface can be packed into a given core size. Thus in the HTGR, we make use of the good thermal conductivity of graphite to transfer heat from the fuel particles to a large surface not normally employed for cooling in a heterogeneous reactor—namely, that of the moderator. In particular, the proposed HTGR fuel element consists of a dispersion of uranium and thorium carbides in graphite compacts that are contained in a graphite can. Thus, about half of the moderator is in intimate contact with the fuel. This scheme has several other very important advantages, which will be mentioned later, but, so far as heat transfer is concerned, the most striking feature is that power densities of the order of 10–15 kw(th) per liter of core are possible, with gas cooling at modest pressures. This compares with the 0.4 kw/liter for a typical Calder-Hall type reactor, and even approaches the 25–30 kw/liter of boiling-reactor types, which, however, need far higher operating pressure.

High-temperature Operation

The basic reason for desiring a high-temperature source for power production is not so much that it promotes a higher thermal efficiency, but that it is a most potent factor in reducing capital cost.

When the coolant temperature is limited between 650° and 750° F, (as in presently operating gas-cooled reactors), large and expensive heat exchangers are necessary, because at these temperature levels one cannot afford to degrade the heat much further to aid in the heat transfer to the steam system. Indeed, the situation is worse than this; even with the largest practical boiler surface area, such gas-cooled reactors operate in a temperature range that requires complex dual-pressure cycles and even then still have turbine-exhaust-wetness problems.

By using reactor outlet gas temperatures of the order of 1,380° F, as in the HTGR, and producing steam at 1,450 psi and 1,000° F, thermal efficiencies of about 40% can be obtained, without resorting to re-heat or dual-pressure cycles. At the same time, substantial temperature differences on the gas side of the boiler surfaces are available which greatly reduce the surface area needed.

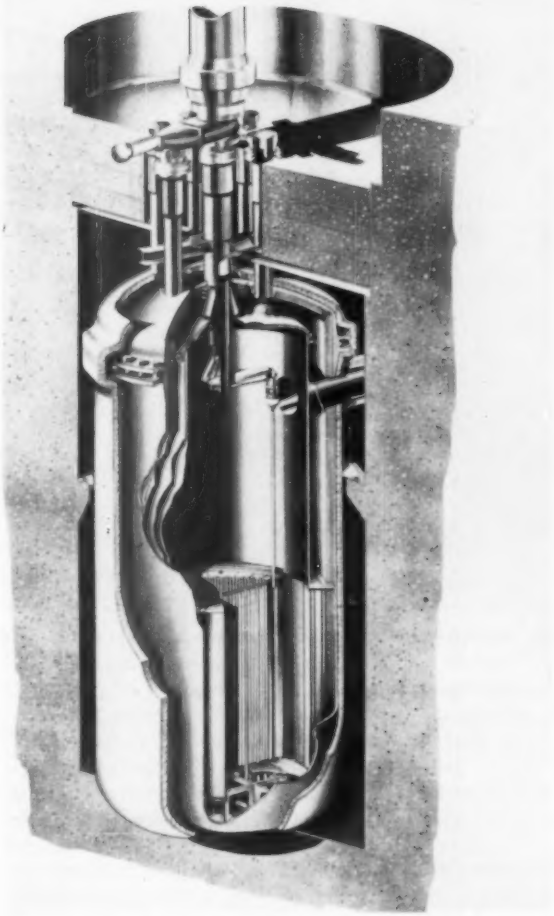


FIG. 1. HTGR REACTOR CORE AND FUEL-HANDLING SYSTEM

Some idea of the magnitude of the boiler size and cost savings made possible by high-temperature operation will be gathered from the fact that the HTGR prototype steam

HTGR Background

General Atomic Division of General Dynamics Corp. is developing HTGR for the Philadelphia Electric Co. and 51 other utility companies comprising High Temperature Reactor Development Associates, Inc. The 40 Mw(e) prototype plant is scheduled for operation by the end of 1963 on the generating system of the Philadelphia Electric Co. at Peach Bottom, in York County, Pennsylvania.

In August the AEC signed contracts with the Philadelphia Electric Co. for design, construction, and operation of the plant and with General Dynamics Corp. covering research and development. Bechtel Corp. is prime contractor to the Philadelphia Electric Co. and HTRDA for plant construction under a fixed-price contract. General Atomic will provide the nuclear steam-supply system, including the reactor, also on a fixed-price basis.

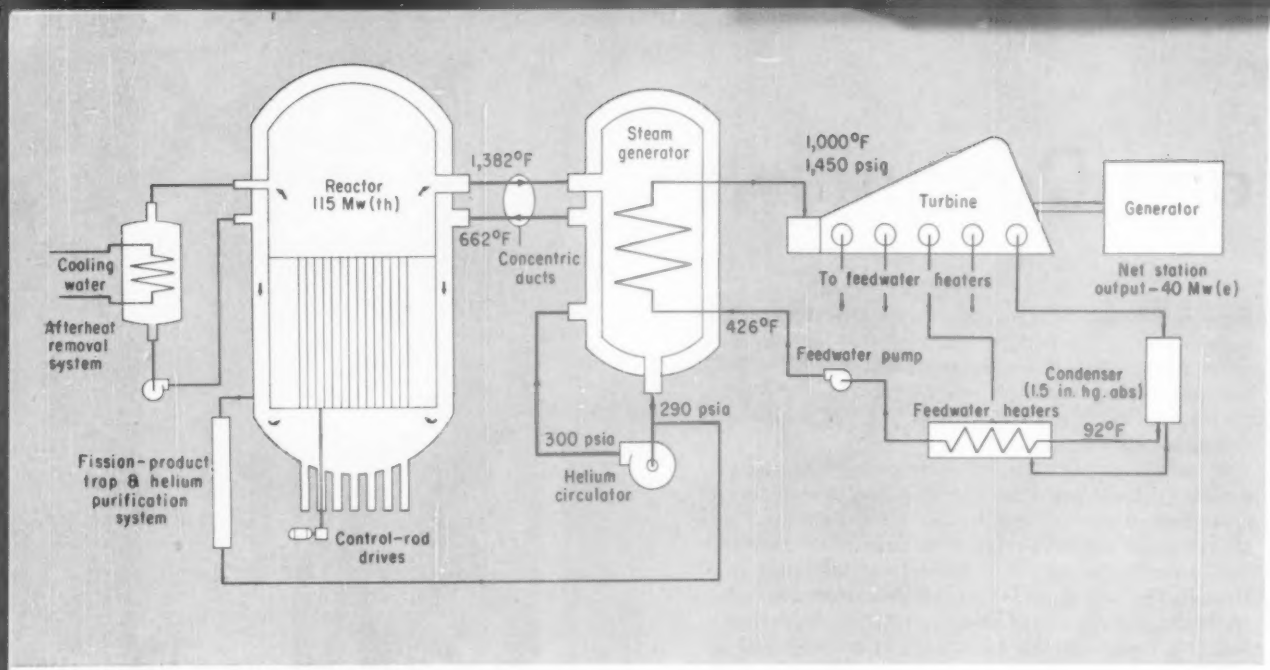


FIG. 2. FLOW DIAGRAM shows He-purge loop that carries fission-products from core to charcoal trap

generator is only about $\frac{1}{20}$ the volume of the Calder Hall boilers, for about the same electric output.

But how does one achieve these high temperatures? Clearly a reactor core that uses only graphite as the structural material would have a head start, for graphite is unique in its combination of strength at high temperature and resistance to thermal shock. The high outlet gas temperature means that the fuel-compact temperatures can be high enough to transfer most of the generated heat to its surrounding graphite can by radiation. This eliminates the need for intimate thermal contact, which is often a problem with more orthodox fuel elements. In addition the high inlet temperature virtually eliminates graphite irradiation damage difficulties.

Fuel Utilization

In taking advantage of the core-design freedom afforded by enriched fuel, it is essential to ensure that these benefits do not result in excessive fuel costs. Ultimately, for such reactors to produce power economically, they must be designed to minimize net fuel consumption by converting as much fertile to fissile material as possible. It is possible, by careful design, to reach the point where a large fraction of the energy produced comes from the relatively inexpensive fertile material rather than from the expensive fissile fuel. Under these circumstances, the make-up fuel cost can become relatively minor. Making the moderator serve the additional duties of cladding material, core structure, and heat-transfer-surface extension, as in the HTGR, is an obvious improvement over the use of otherwise unnecessary absorbers of neutrons for these purposes. Indeed, for high-temperature operation, the use of metals (e.g., stainless steel) for cladding and fuel dilution implies gross neutron absorption.

A related aspect of fuel-element material and design, which affects the over-all economy, concerns the fuel burnup fraction obtainable and the corresponding core lifetime. A high conversion ratio alone is insufficient to keep fuel costs down if, because of radiation damage, the fuel must be frequently reprocessed. The cost of this operation may far outweigh the savings in makeup fuel cost. Thus, fuel dilution by the moderator offers a very important potential advantage—it permits far greater fuel dilution than would otherwise be possible and thereby minimizes radiation damage.

Typically, a homogeneous fuel element for a large reactor might consist of 1 atom of U^{235} to 40 atoms of fertile material to 4,000 atoms of moderator. If only as little as 0.1% of the atoms in the fuel element were allowed to undergo fission (corresponding to 1,000 Mwd/tonne burnup in natural uranium), the burn-up of fertile plus fissile material would be 100,000 Mwd/tonne. Clearly, the potentialities of high dilution are considerable. The desirability of achieving high burnup per charge goes beyond the requirement of just minimizing over-all fuel costs: freedom to operate without domination of economics by factors outside the plant operator's control (like buy-back and reprocessing costs) is in itself a worthy goal.

Safety

Ideally in a reactor intended for large-scale power production, safety should be inherent in the design features, rather than provided by elaborate auxiliary devices. The HTGR approaches this ideal in three major ways:

- The intimate mixture of fuel and graphite moderator within the fuel elements ensures a prompt moderator temperature coefficient. This and the enhanced heat capacity of the homogeneous-type fuel elements combine to limit any fuel-temperature overshoot.
- The specific energy content of the helium coolant is far lower than that of any liquid pressurized to operate substantially above the atmospheric boiling point, an advantage secured without undue sacrifice of high power density. This means that adequate secondary containment can be provided for the largest systems at a low cost.
- The side and bottom graphite reflectors, which are normally maintained at reactor coolant inlet temperature, constitute a built-in heat sink in the event of temporary loss of the main heat-rejection system.

HTGR PROTOTYPE

We have carried out preliminary design studies that embody the above features for large-scale HTGR's of 150 Mw(e) and 325 Mw(e). Fuel-cycle costs as low as 1.5 mills/kwh and capital costs of $250/kw appear entirely within reach for plants of this size.

The 40-Mw(e) HTGR will be a prototype for such larger power plants. The fuel temperatures and gas pressures will be approximately the same as those required for the larger plants. Also, the prototype plant equipment will be sufficiently large so that, once developed, it will serve as the basis for the design of larger equipment needed for full-size commercial plants.

Reactor data and principal operating conditions for the graphite-clad core are summarized in the table. Fig. 1 shows the general arrangement of the reactor and Fig. 2 the flow diagram.

A core consisting of metal-clad graphite fuel elements may be used initially for the start-up and testing of the prototype plant. During the initial operational testing phase there would be a gradual transition to the graphite-clad fuel elements. The reactor plant is designed to accommodate these core changes. The purpose of this approach would be that it might permit earlier operation and testing of the plant and components. Since metal cladding imposes a temperature limitation on the fuel surface, some sacrifice in steam conditions and thermal output would occur during the transition period. However, the steam conditions (850° F and 850 psi) with the metal-clad core are still high. The corresponding plant rating could still be kept in the range of 25,000 to 30,000 kw.

Reactor Core

The reactor core is comprised of 855 cylindrical elements, 3.5 in. in diameter, in a closely pitched equilateral triangular array. (Approximately 40 of these elements are control rods arranged in a symmetrical pattern.) The coolant gas passes through the tricusp-shaped passages formed by the cylindrical elements. The bottom and top reflectors, each 2 ft thick, are integral parts of the fuel elements. The side reflector, which extends the full height of the fuel elements, is also 2 ft thick and is made up of a row of dummy graphite elements and a concentric ring which encloses the core.

Incoming coolant gas passes, in part, through the multiple coolant passages formed by the thermal shield and the pressure-vessel wall and, in part, through the side reflector before passing up through the reactor core. A plenum chamber above the core, formed by a shroud which serves as a thermal barrier between the outgoing hot helium and the incoming cooler helium, connects to the coolant outlet from the reactor.

Fuel Element Design

The outstanding performance of the HTGR derives principally from the very high operating temperature of the fuel-moderator elements (i.e., approximately 2,000° F and 3,000° F for element-surface and centerline temperatures, respectively). These high temperatures do not result in mechanical or structural problems since the elements are fabricated almost entirely of graphite, which has an increasing strength up to about 4,000° F.

The fuel element consists of a graphite sleeve with end fittings which contains the fuel compacts and both top and bottom reflector. The fuel compact consists of U^{235} and Th^{232} in the form of carbides dispersed in a graphite matrix (1 U^{235}: 10 Th : 700 C atom ratio). At the operating temperature of the fuel these carbides are thermodynamically stable. The mean distance between particles of fuel and fertile material is larger than the range of fission-fragment recoil; most of the graphite matrix of the fuel compact is thus free from fission-fragment damage. Because of the high U^{235} burnup expected [approximately 0.6 fission per initial fissile atom for the 40-Mw(e) prototype to around 2 for the large plants], the fuel and fertile material are mixed to avoid a large change in power distribution during core burnout. In addition, mixing of fuel and fertile material results in a useful contribution to the prompt negative temperature coefficient from Doppler broadening of the thorium resonance.

Fission-Product Control

Although mixing the fuel and moderator and eliminating the fuel-element metal cladding eases the cooling problem, improves neutron economy, and allows high-temperature operation, it introduces the problem of fission-product diffusion. This problem would probably be associated with all really high-temperature reactor systems, for at high temperature any cladding system—metallic or otherwise—is to some extent permeable to some fission products.

In the HTGR, the approach is not to attempt hermetic containment of all the fission products within the fuel elements, but rather to minimize the loss by using relatively impervious graphite cladding and to control the fate of those products that do escape.

Fission-product control starts in the fuel compacts where roughly one-half of the fission-product elements formed can be expected to remain fixed, either because of their own nonvolatility or because of their formation of stable, nonvolatile carbides. The principal elements in this group are Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, La, Ce, Pr, Nd and Pm. Of the remaining fission products, those that manage to escape through the highly impermeable graphite are carried to an external fission-product trapping system by a helium purge stream that flows between the compact and the outer graphite sleeve. The purge stream connects to the external trapping system at the bottom support point of the elements. From the trap the helium purge stream returns to the primary circuit. The principal advantage of this system over a by-pass system operating on the primary coolant stream is that the chemically reactive or condensible fission products are prevented from plating-out in the primary circuit prior to reaching the trap. Furthermore, the fission products are relatively undiluted when they reach the trap and thus trapping difficulties are decreased.

The scavenging-helium flow rate and the permeability of the outer graphite sleeve are selected to limit the back-diffusion of fission products (principally Ba, Sr, Cs, I) into the primary circuit to an amount consistent with the criterion of direct maintenance on the plant equipment. The scavenging flow can be set at as much as 10^5 times that of the fission products without excessive demand on the flow capacity of a trapping system of reasonable size. With this flow and a low contamination buildup limit on

FIG. 3. HTGR FUEL ELEMENT emerges from autoclave after thermal cycling test. Clad here is metal instead of graphite

the primary circuit surfaces (taking into account delay and decay of the fission products), a graphite with a permeability of 10^{-6} to 10^{-7} cm²/sec (room-temperature permeability to helium) is adequate for the outer sleeve.

In addition to minimizing the escape of fission products, the graphite-contained compact serves to delay or hold up those which are finally collected in the trap. This holdup allows the larger energy release of the volatile short half-life fission products to be given up in the element rather than in the trap, where it is conveniently removed by the primary coolant.

The external trap is currently under development and is likely to be composed of activated charcoal; the initial stages will be water-cooled and the final stage may be refrigerant-cooled.

Primary Coolant System

The primary-coolant cycle (see Fig. 2) is a closed circuit which conducts the helium coolant from the reactor-vessel outlet to a single steam generator, to the main circulators, and back to the reactor-vessel inlet. The duct between the reactor vessel and the steam generator is made up of concentric pipes. The hot gas (1,380° F) flows through the inner pipe to the steam generator and the cooled gas (660° F) returns to the reactor via the annular duct. Regenerative heating of the cool gas in the annular duct by the hot gas in the central line is reduced to a small effect by insulating the inner duct with dead gas space. An important advantage of the concentric ducts is that the outer, pressure-bearing pipe is cool whereas the inner pipe carrying the hot gas has only a small pressure differential applied to it. In addition, the thermal stresses at the penetrations of the reactor vessel and steam generator are considerably reduced by the concentric pipe.

In passing through the steam generator, the hot coolant gives up its heat to make 367,000 lb/hr of 1,000° F, 1450-psi superheated steam and leaves the generator at 630° F. The coolant then returns via the helium circulators and an outer shell within the steam generator to the reactor vessel through the outer annulus of the concentric duct. Since concentric flow of the hot and cold helium coolant is used throughout the plant, all pressure-containing surfaces, including the reactor vessel, are exposed only to the low-temperature (660° F) coolant. Hence, carbon steel may be used for most of the structural parts.

Two circulators in series circulate helium through the coolant loop. These are canned-motor, single-stage, centrifugal compressors with overhung impellers. The compressors circulate 80,000 cfm of helium (480,000 lb/hr) at 290 psia, with an inlet temperature of 633° F and a pressure rise of 5 psi in each (a total of 10 psi) when operating at design speed of 3,475 rpm. The drive motors are rated at 2,500 hp with a 2,400-volt, 3-phase, 60-cycle power supply. To provide a variable helium flow rate, the compressor drive motors are operated from a variable-frequency power supply.

The compressor-motor assembly is completely enclosed within a sealed can to prevent helium leakage. Cleaned helium fed to a labyrinth-type shaft seal prevents contaminated helium from entering the motor compartment.

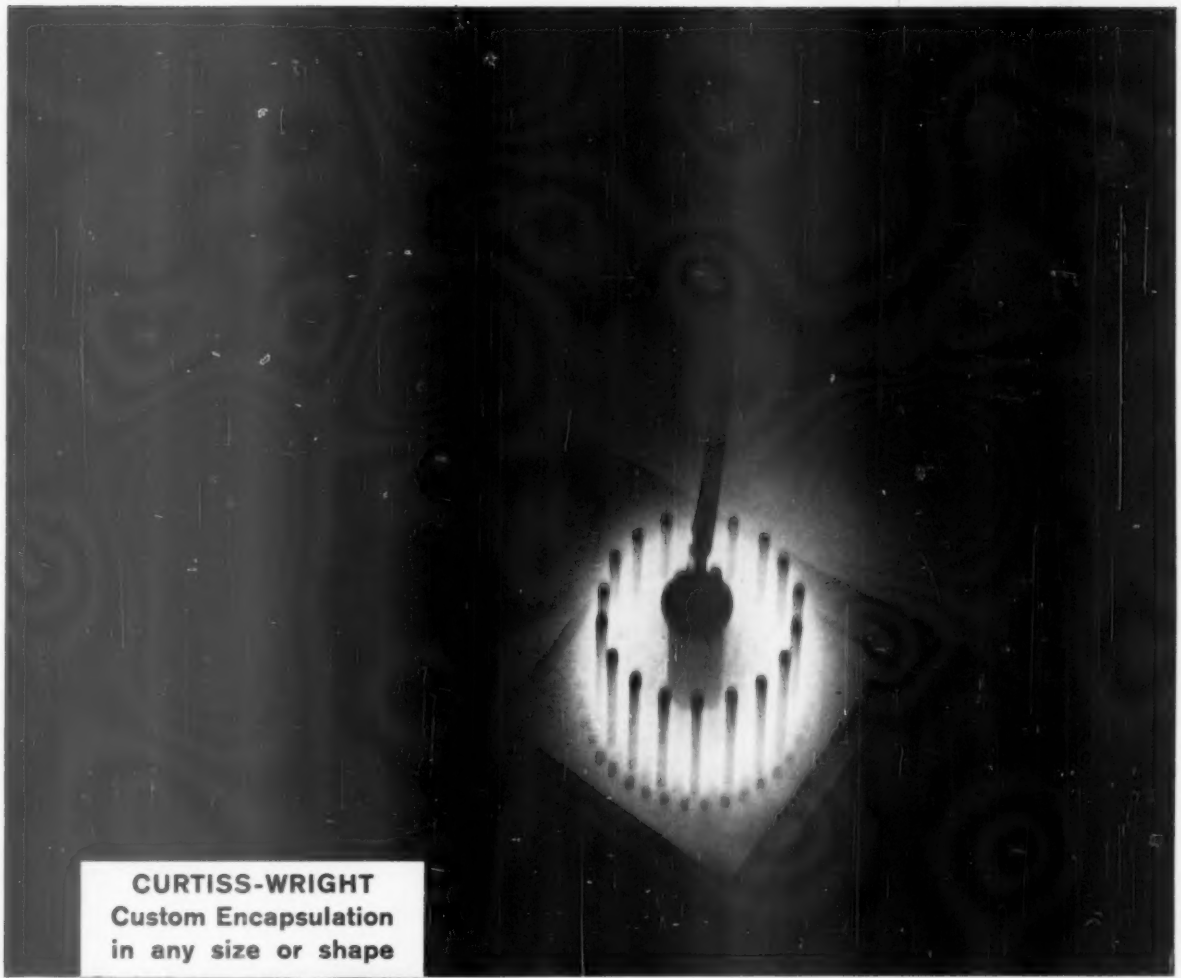
Continuous bypass purification of the helium in the primary system is provided to maintain minimum equilibrium impurity levels. We anticipate that total impurity levels of less than 10 ppm will be necessitated by mass-transfer considerations. Both cold adsorption and hot, chemically reactive traps are being considered to remove oxygen, nitrogen, water vapor, and other gaseous impurities. Two-stage high-efficiency cyclone dust collectors remove entrained solids. A portion of the cleaned helium is utilized for sealing valves, circulator cans, and other buffer-sealed enclosures.

Development Program

The HTGR development program, underway since 1957, has emphasized the development and testing of the fission-product control and trapping system. Associated with this work have been tests of the ability of impervious graphites to contain fission products; development and tests of the performance of graphite-uranium-thorium fuel bodies; and tests to demonstrate that the contamination of primary circuit components will be low enough for direct maintenance. Much of this work involves in-pile capsule and loop experiments.

Experiments on mass transfer of carbon in the presence of coolant impurities, in addition to direct work on the coolant purification system, are being carried out. Heat-transfer experiments to verify the reactor-core thermal design are underway. Much of the mechanical equipment (helium circulators, control-rod drives, etc.) requires development and testing to insure a low coolant leak rate and reliable operation.

In the reactor-physics area there are several problems associated with the high operating temperature, with the high burn-ups anticipated, and with the use of the thorium-U^{235} fuel which are under study.



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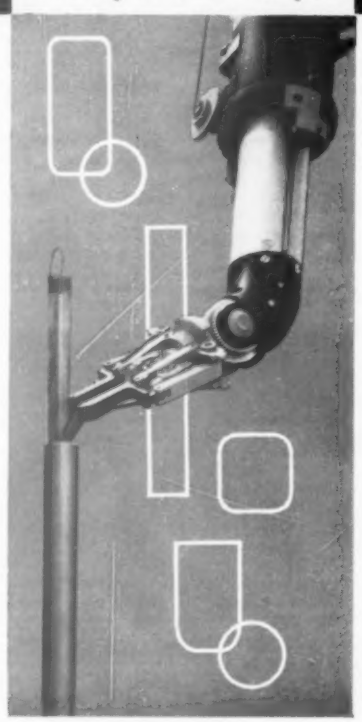

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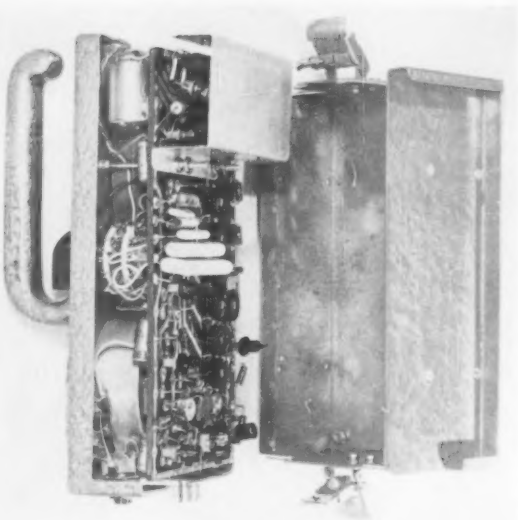

FIG. 1. TRANSISTORIZED counting-rate meter uses interchangeable air-proportional probe (a), scintillation probe (b) and G-M probe (c)

FIG. 2. METER INTERIOR. Printed circuits permit easy accessibility

Transistorized Portable Counting-Rate Meter

By WILLIAM W. GOLDSWORTHY
Lawrence Radiation Laboratory, University of California, Berkeley, California

This transistorized portable counting-rate meter (Fig. 1) is capable of detecting alpha, beta, gamma or neutron radiation by means of interchangeable detector probes. Because of its versatility, compactness, ease of servicing and low battery drain, this instrument should be an excellent choice for a multipurpose radiation detector.

Several of these instruments have been used successfully for more than a year at this laboratory. Maintenance

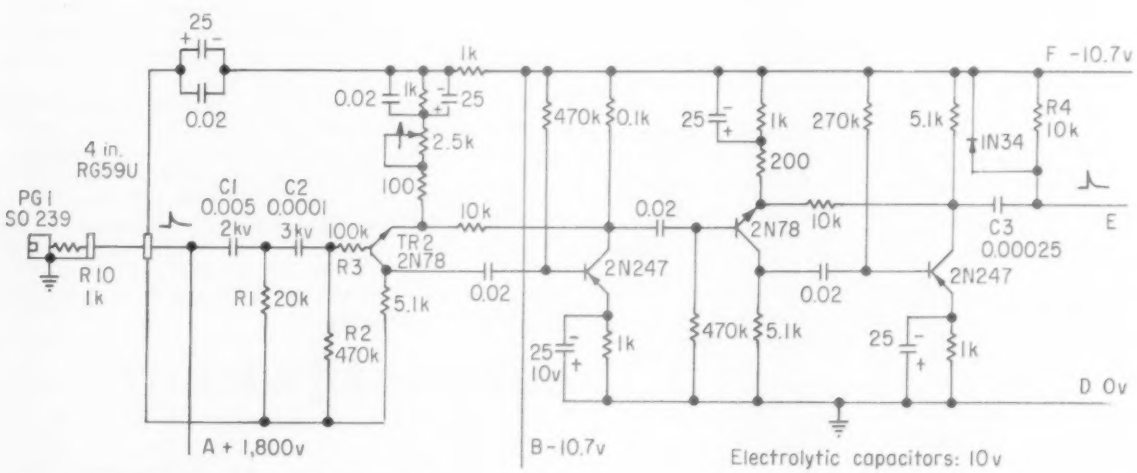

FIG. 3. AMPLIFIER CIRCUIT of counting-rate meter

LOW LEVEL GAMMA RAY DETECTION

WHAT'S NEW in applied nuclear physics. Well for one thing, we are,

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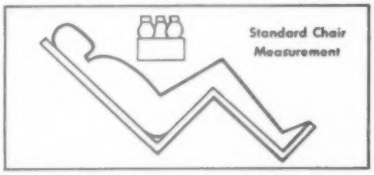
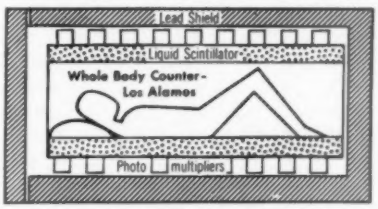
WHAT ELSE IS NEW . . . Whole Body Counting has been a field of advanced research at a few major laboratories here and abroad. The term "whole body counting" means the detection and measurement of gamma radiation from the whole human body as a single extended source. The radioactivity may have been taken up intentionally as in tracer medicine, or it may consist only of the naturally occurring gamma emitting isotopes found in the human body. For the latter studies a very special low level or controlled background facility ("COBAFAC") is required because the natural radioactivity in standard materials (most shielding materials included) contains the same orders of magnitude of radioactivity as does the normal human. So the general problem requires the subtlest of techniques in all aspects.

The history of the low level whole body counting field begins, as is usually the case in "new" fields, with experiments more than two decades ago when the problem of radium poisoning (in brush-licking dial painters) was brilliantly diagnosed by Harrison Martland, New Jersey Medical Examiner. Applying the available nuclear physics techniques, R. D. Evans made the first geiger counter measurements of radium ingested in humans. These determinations established general techniques (the "one-meter arc measurement", the "closed-background", etc.) and laid the foundations of today's tolerance levels.

About ten years ago, Sievert of Sweden and later Burch and Spiers of England constructed large volume, high pressure gas detectors for the determination of low level gamma radiation in the human body. The program for radium and thorium measurement led workers at Argonne National Laboratory, Div. Radiol. Phys., to the use of scintillation crystals of several inches diameter and specially constructed shielded



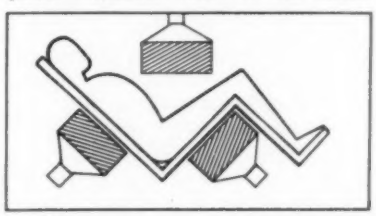
rooms. The picture above indicates the "standard chair" position and crystal. This measurement is made with a large NaI crystal coupled to one or more photomultipliers. During the early 1950's, Los Alamos physicists had developed large volume liquid scintillation counters for their elegant experiments detecting the presence of the neutrino. Subsequently, experimenters modified these highly efficient systems to measure radium burden in dogs (the "K-9 counter") and then natural potassium-40 in normal humans. This sketch illustrates the early form of this liquid scintillation detector. A trough is used to insert the subject



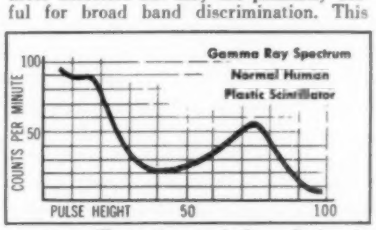
and the liquid scintillator solution is viewed by about 100 photomultipliers. A later version, the Geneva Counter, is a walk-in counter using relatively few 16"D photomultipliers to achieve a moderate energy resolution.

Advances in the technology of large crystals, photomultipliers and multi-channel analyzers have quickened interest so that there are between fifteen and twenty low level facilities operating or under construction.

The requirements of the systems and the state of the art may be summarized. First, of the many possible shielding materials (sugar, wood, water, etc. have been seriously considered) the standard material in use today is iron suitably treated to reduce surface contamination. A significant reduction in the low energy contribution to background is made by the addition of a lining of a few millimeters of lead. Second, the detector should have as high efficiency as possible. The 4π liquid scintillation tank has high geometric efficiency, is insensitive to source distribution, and uses a relatively compact shield. Another efficient system is an assembly of large plastic scintillators shown in this sketch.



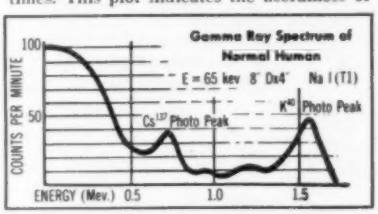
If rapid assays of gross gamma emitters are required, such high efficiency systems (liquid or plastic are the most economical in large sizes) are indicated. Some degree of energy resolution may be obtained with these detectors but they are primarily useful for broad band discrimination. This



spectrum illustrating typical resolution in liquid or plastic detectors is an early one and thus does not markedly indicate Cs^{137} although the potassium-40 peak is easily distinguished.

The single large NaI crystal detector has high stopping power (or "intrinsic efficiency") but is about 40 times less sensitive because of its small solid angle. However, the differential background for any particular gamma ray is low enough that counting times are not prohibitively long. The low geometric efficiency arises from the distance-versus-uncertainty condition requiring use of reproducible geometry ("one-meter arc", "standard chair", etc.) and a shielded room. Similarly in thyroid uptake measurements a distant determination is usually required to minimize sensitivity variations due to uncertainty in the location of the thyroid.

If identification of isotopes is desired, the advantage of the good resolution of the NaI crystal may offset longer counting times. This plot indicates the usefulness of



large NaI crystals in energy measurements in vivo. The Cs^{137} peak present in all living subjects has been growing steadily during this decade. Many other spectra of isotopes in vivo have been obtained by the Argonne group experimentalists. Also, the positional sensitivity of the lower efficiency techniques may be useful if localization of the activity is desired. Thus a single large crystal can be used for standard whole body determinations and also positioned or automatically scanned for distribution studies.

Finally, the electronics required for these installations may be as simple as an integral counting scaling system (or at most, several single channel analyzers) for the plastic and liquid scintillators, or as complex as a large multichannel installation for the analysis of isotopes.

Many factors influence the choice of systems. For example, the problems associated with the handling of the inflammable liquid scintillators must be weighed against increased electronic costs of the NaI systems. The sample load must be compared to the degree of analysis desired. A number of uses of these facilities are beginning to emerge: 1) Measurement of normal K^{40} to determine the lean/fat ratio and its relation to physiological conditions. 2) Whole body low level tracer studies in the dynamics of metabolism. 3) Whole body scanning for the localization of isotopes. 4) Radioactivity determinations on large samples of foodstuffs subject to fallout contamination and consumer products in industrial tracer uses.

At ATOMIUM we have designed a number of systems for low level detection combining the best features of past work. If you are considering the usefulness of a low level counting facility in your work, we should be happy to take up the discussion where we leave off here and send you a proposal best suited to your experimental requirements. If you are interested in special nuclear systems, write us at

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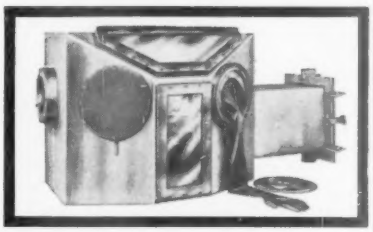

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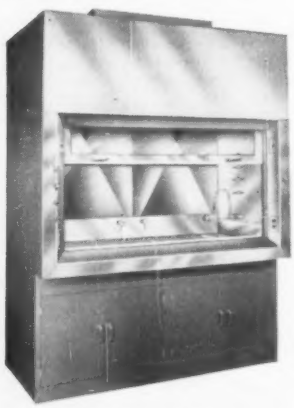

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INSTRUMENTATION AND MEASUREMENTS

This article starts on page 92

has been practically limited to battery replacement, which is at a minimum because of the low power consumption.

Exclusive of the probe, the instrument weighs under four pounds and measures $4 \times 4 \times 9$ in. The single battery, which supplies all power requirements, lasts more than two weeks under continuous operation or up to a year under normal intermittent operation. Production and maintenance are simplified by the printed circuit, as well as by using only standard parts and as few mechanical fabrications as possible (Fig. 2).

Several features are not normally combined in an instrument of this size: five individually calibrated ranges, a completely shielded case and meter well, and an anode voltage supply capable of driving the interchangeable proportional, G-M and scintillation probes.

Circuitry

The schematic for the instrument is shown in Figs. 3–5. Pulses developed at the probe enter the instrument through receptacle PG1, and after passing through the input shaping and protecting circuits, pass through a four-transistor feedback amplifier having a maximum gain of ~70 db. The amplified pulses are then fed through a differentiating network and into a univibrator metering circuit, which drives the indicating meter.

To develop anode voltage for the various probes, a transistor blocking oscillator generating a 2-kc square-topped pulse waveform is followed by a stepup transformer, a Cockcroft-Walton voltage multiplier, a corona voltage regulator, a ripple filter and a resistor dropping chain.

As in most portable radiation counters, the radiation-detecting probe is subjected to a great deal of mechanical shock and vibration, which may induce low-frequency noise into the amplifying system. To attenuate this noise, transistors are available having good gain-bandwidth products as well as low power consumption. These transistors can greatly attenuate the undesirable low-frequency microphonic noise, as well as low-frequency transistor noise, without appreciably affecting the pulse-amplifying properties of the amplifier. Also, the instrument's accuracy and indicating linearity can be greatly improved at high counting rates by allowing pulses entering the pulse-amplifying system to be as narrow as possible to prevent pulse pileup and amplifier blocking.

Input-Pulse Shaping

The pulses generated by the detecting probe are shaped to pulse widths of ~2 μsec by the rise time of the amplifier and by the fall-time-determining resistor R1, which is effectively connected in parallel with the probe's output capacity by the coupling capacitor C1.

Protective Circuit

From the input-shaping network, the pulse passes through a protective coupling and biasing network, consisting of R2, R3 and C2, to the base of the input transistor. If this protective circuit were left out, the input transistor would be easily destroyed by accidental probe shorting or by the current transients induced when changing probes. The voltage rating of the base coupling capacitor C2 is 3,000 volts since the full anode voltage appears momentarily across this capacitor when the input circuit is shorted.

Amplifier

The desired pulse-amplifier characteristics are high input impedance, relatively good bandwidth, ~70 db of gain, good stability and good overload characteristics.

The amplifier chosen is a four-stage inverse-feedback amplifier, alternately using NPN and PNP transistors in two-cascaded, two-stage, last-collector-to-first-emitter feedback pairs. Both of these two-stage feedback pairs are identical with the exception of a feedback control appearing in the input feedback pair. This control serves as the coarse gain control for the instrument, giving a gain variation of about 20. Direct-current emitter feedback is used in all stages to further reduce amplifier gain drift with temperature. The alternate use of NPN and PNP transistors reduces overloading difficulties by allowing pulses to drive transistor bases toward cutoff only, rather than toward heavy conduction, thereby reducing amplifier blocking caused by excessive charging of the interstage coupling capacitors.

Output Shaping

Since low-frequency noise generated by the input transistor, along with low-frequency microphonic noise generated in the radiation probe, is present in the amplifier output, it is desirable to add

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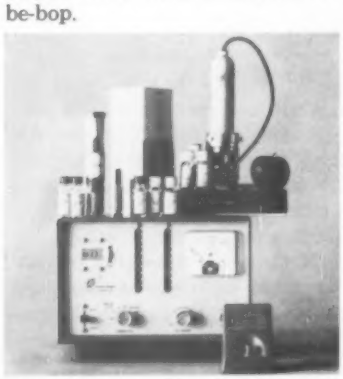

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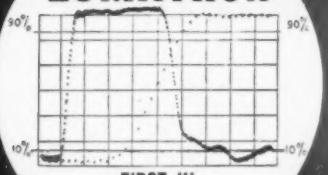

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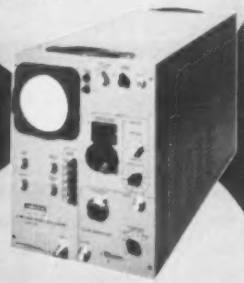

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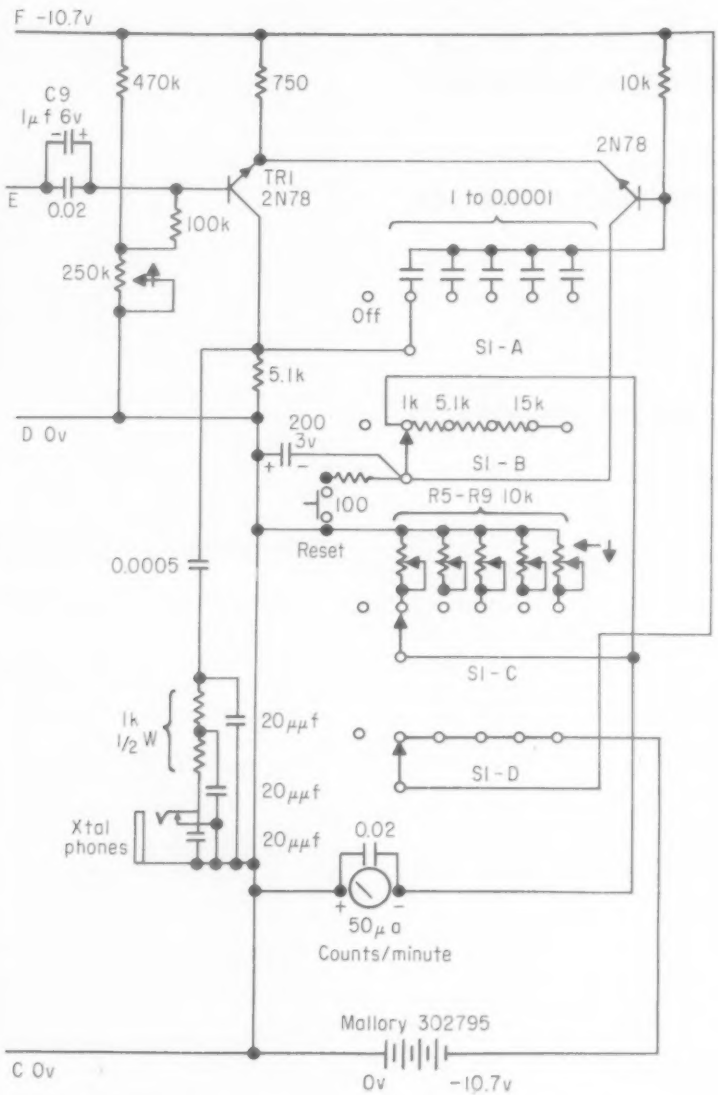

FIG. 4. METERING CIRCUIT of counting-rate meter

some low-frequency attenuation. This is accomplished by differentiating the amplifier output in the coupling circuit consisting of C3 and R4. The diode across the output of this circuit removes the undershoot produced by this differentiation and insures the proper pulse shape for driving the metering univibrator. This output-pulse shaping also reduces amplifier dead time by speeding base-line recovery at the input to the metering univibrator.

Ratemeter Circuit

The counting-rate meter uses a conventional univibrator circuit. The meter deflection is proportional to the average on-time of the univibrator circuit, which is a product of the input-pulse rate and the selected on-time per pulse chosen by the range-selector switch S1. The univibrator's input-bias circuit provides for the fine gain adjustment of the instrument; capacitors C4 through C8 provide for the basic counting-rate range selection; and the meter shunts R5 through R9 provide for the fine calibration of the individual counting-rate ranges.

Since the speed of response of a counting-rate meter is proportional to the pulse rate, it is desirable to alter the metering time constant in relation to counting rate. For this reason, the

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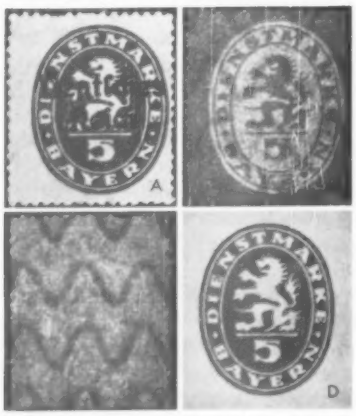

Bavarian stamp of 1920 (Scott No. 052). A. Visible light photograph. The design is green and the "Deutsches Reich" overprint is black. B. Soft x-ray radiograph. Details of both design and paper visible. Design is "negative," indicating absorption of x-rays by the ink. C. Electron radiograph. Only the details of the paper are shown. D. Electron-emission radiograph. The design is "positive," indicating a relatively high electron emission from some heavy element in the ink. The overprint cannot be seen.

This is a clever scheme to snare the attention of those who use philately for a hobby and radiation for a livelihood. Having gained your attention, we must reward you for it. The reward takes the form of a handsome 24-page book which contains not only a discussion of the above illustrations but (much more important) of general techniques for radiography by emitted electrons, transmitted electrons, soft x-rays, hard x-rays, and gamma rays; and (most important) operating data about the several new and newly improved Kodak films for all manner of radiography and x-ray diffraction.

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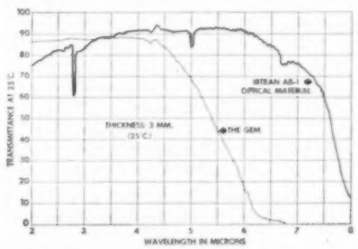

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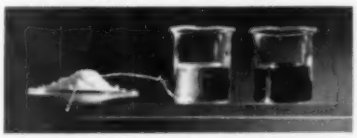
Type AB-1 is only the beginning of the *Irtran* business, we suspect. Quartz was fine when lead sulfide was the practical detector; PbS quits at 4μ. Now the longer wavelength sensitivity of cooled lead selenide, lead telluride, and indium antimonide has outrun the transparency of good old quartz. Soon the boys will be banging on the 8 to 13μ window of the atmosphere. For lenses with optical power they'll want infrared-transmitting material of higher refractive index. *Type AB-1* may be only the beginning.

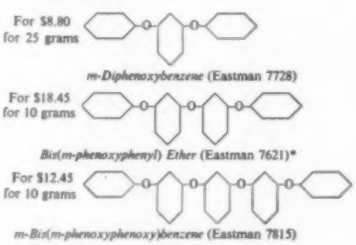
With what excitement the specifications for us to quote on will be drawn up and shot off to Eastman Kodak Company, Special Products Division, Rochester 4, N. Y.!

600°F is tougher than 350°F



To demonstrate how passably these two liquids and this solid perform as oxidation-, corrosion-, and radiation-resistant lubricants for gears and bearings operating up to 600°F in flying objects and other up-to-date kinds of machinery must have taken a tidy chunk of government money. We can cluck like a frugal taxpayer, since only a pittance found its way into our pockets.

Now that the pure, undoctored, unsubstituted meta-linked polyphenyl ethers are revealed to rate high for chemical sturdiness, lubricity, and retention of the liquid state over a broad temperature range, we find it in our hearts to enable the experimenter to acquire them in a small, quiet commercial transaction without diplomatic maneuvering.


For $8.80 for 25 grams
m-Diphenoxybenzene (Eastman 7728)
For $18.45 for 10 grams
Bis(m-phenoxyphenyl) Ether (Eastman 7621)*
For $12.45 for 10 grams
m-Bis(m-phenoxyphenoxy)benzene (Eastman 7815)

Perhaps one of our markets for these polyphenyl ethers will be for use as foils against which to demonstrate the superiority of new classes of lubricants as yet unrevealed, just as the polyphenyl ethers stand up for many hours to conditions that devastate 350°F lubricants to stiff sludges or vapors in minutes. Two decades ago, when we were in the high-vacuum business and considered ourselves pretty smart in diffusion pump liquids, we developed some phlegmatic esters that now serve as the goats for the polyphenyl ethers to beat.

Small, quiet transactions are the mainstay of the Eastman Organic Chemicals Department of Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company). Our current "List No. 41" will tell you of our organic chemical wares, some 3700 of them.

*There has been some 40° to 800°F talk about this one.

Prices are list and subject to change without notice.

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This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

This article starts on page 92

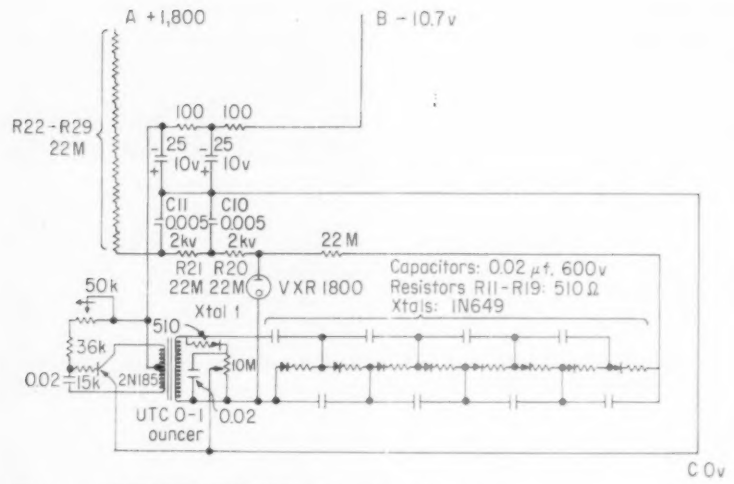

FIG. 5. ANODE-SUPPLY CIRCUIT of counting-rate meter

metering time constant is changed automatically with range switching to allow for rapid reading of high counting rates and accurate reading of low counting rates.

Five individually calibrated ranges are supplied to provide a wide range of counting rates with good indicating accuracy. A panel-mounted push switch is also provided for zeroing the indicating meter.

To insure proper operation of the univibrator circuit at low counting rates, its input coupling capacitor C9 was made large to prevent premature univibrator turn-off. It was found that small coupling capacitors at this point provided for good triggering, but when long univibrator on-times were required for low counting rates, the univibrator would turn off prematurely. The cause was found to be a too rapid charging of the univibrator's input coupling capacitor by the change in the transistor TR1 base current. A large capacitor for this coupling circuit sufficiently decreased the rate of change of base bias for transistor TR1 to allow the univibrator to stay triggered for the long intervals desired at low counting rates.

R-F Shielding

Since the instrument is often used in the vicinity of large particle accelerators, it was necessary to shield against the pulsed r-f fields. R-f attenuating circuits in the form of low-pass *RC* filters are placed at the phone jack and the probe receptacle. The components providing r-f filtering in the probe input circuit are the capacitance of a small section of shielded cable along with resistor R10 and the input base capacity of TR2 along with resistor R3. As was pointed out earlier, there are no large holes allowing r-f leakage through the case, since all operable joints are well lapped and the indicating meter is enclosed in a shield well with one of its terminals directly grounded to the case.

Anode Supply

The anode supplies in many presently available transistorized portable counting-rate meters leave much to be desired. They are often lacking in voltage stability and current capacity.

Insufficient stability causes poor indicating accuracy and makes frequent readjustments necessary. Neither of these limitations can be tolerated in an operational monitoring instrument. Insufficient current capacity in many cases causes the unit to require an excessively long warmup period and to have an output voltage more easily affected by moisture on the insulation of the anode-supply circuits.

The anode supply used in this instrument has a corona regulator for output-voltage stability. Current output is 10 μa—5 μa to avoid erratic operation of the regulator and 5 μa of usable current delivered to the probe receptacle PG1.

To develop the required anode voltages, a large amount of voltage stepup is required from the 10.7-volt battery. To accomplish this, a pulsed square-wave voltage generated by a transistor blocking oscillator circuit is supplied to a Cockcroft-Walton voltage multiplier through a stepup transformer. The multiplier output is then fed into the corona regulator.

Two means are used for varying the output voltage of the anode supply. Ten 22-megohm resistors are incorporated between the regulator output and the probe receptacle. The coarse adjustment is obtained by providing a resistive load in parallel with the probe, which draws the required current to produce the correct voltage drop in the 22-megohm resistors. The probe-loading resistors are incorporated as integral parts of the probe units.

For fine voltage adjustment, an additional rectifier circuit having an adjustable 0–300-volt output is placed in parallel with the input to the Cockcroft-Walton multiplier. The output polarity of this circuit can be reversed by reversing crystal 1. When the voltage supplied by this circuit and that supplied across the corona regulator are placed in series, the two voltages can be made to add or subtract giving adjustable voltage ranges of 1,500–1,800 volts or 1,800–2,100 volts at the power-supply end of the resistor-divider chain.

To protect the silicon diodes against damage by accidental shorting of anode-supply components, resistors R11 through R19 limit peak currents to a safe value.

Resistor-capacitor combinations R20-C10 and R21-C11 provide for filtering the ~2-kc blocking oscillator signal that appears in the rectifier output. Resistors R21 and R20, along

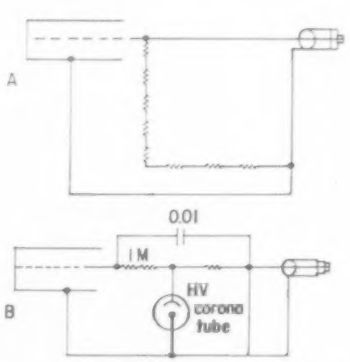

FIG. 6. G-M AND PROPORTIONAL-PROBE alternate circuit schemes; resistors are 22M unless otherwise indicated

with resistors R22 through R29, function as voltage-dropping resistors when the instrument is used with probes requiring voltages of <1,500 volts.

Probe Use

Proportional or G-M probes with operating voltages of 1,500–1,800 volts can be operated directly with this instrument by connecting to the input jack PG1. When using probes requiring <1,500 volts, however, the schemes shown in Figs. 6 and 7 can be used. In both schemes, a single cable connection between instrument and probe is maintained to make all probes interchangeable.

The connection for a G-M or proportional counter makes use of a parallel resistor to load the output voltage of

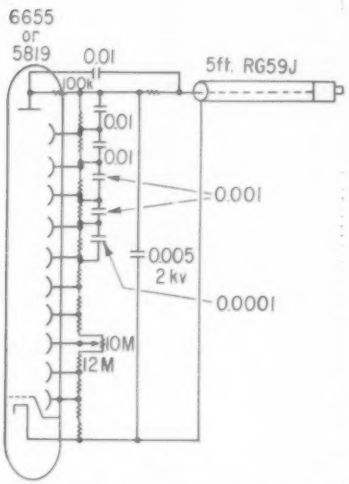

FIG. 7. SCINTILLATION-PROBE circuit; unlabeled resistors are 22M

the supply down to the operating voltage of the counter tube, as shown in Fig. 6A, or makes use of a second corona tube in parallel with the counter tube's voltage source to provide the proper operating voltage, as shown in Fig. 6B.

When a photomultiplier tube is used, the dynode-supply resistors load down the voltage supply to the proper operating voltage, as shown in Fig. 7. An adjustable voltage applied to the third dynode of the multiplier will further control its gain by defocusing. This additional control allows an easy preset adjustment of gain of several different probes, which can be used interchangeably with the instrument.

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission.

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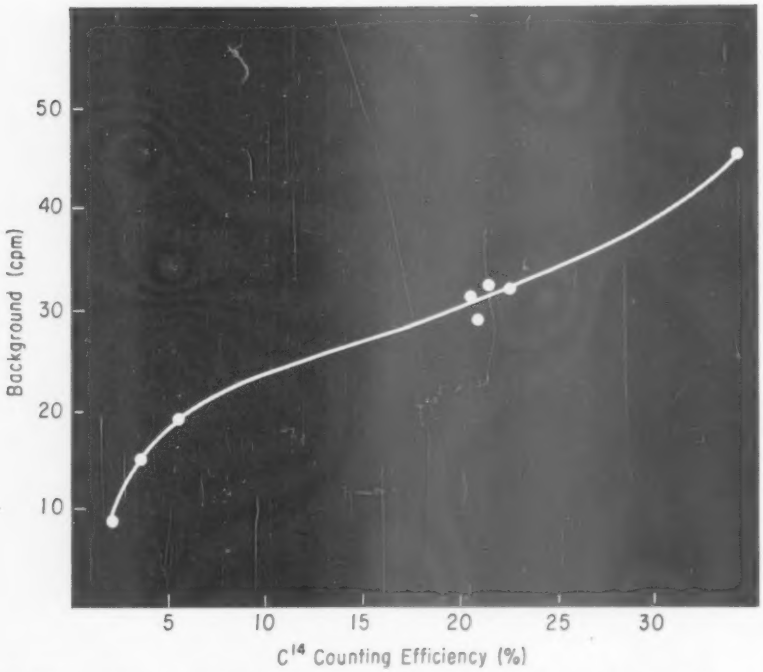

BACKGROUND in liquid-scintillators is far-from-linear function of counting efficiency

Background vs. Efficiency in Liquid Scintillators

By FLOYD R. DOMER and F. NEWTON HAYES
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

There is a correlation between background and counting efficiency in liquid-scintillation counting. Different samples can have considerably different detection efficiencies because of changing chemistry and quenching. With this change of efficiency comes a change in background counting rate, but the relationship between the two is not linear. In fact, it is not even simple.

Except for procedures in which the chemistry of the counting solution is carefully controlled, most users have already abandoned the external standard in favor of an internal one. An external standard is a separate solution counted to determine background. In contrast an internal standard is a radioactive solution added to the sample being counted. But it may still be a habit to use a single background sample for a group of counting samples.

The difficulty is that the background spectrum viewed by a liquid scintillator is not flat; the number of counts per unit energy interval is not a constant function of energy. As performance is reduced by quenching, the scintillator recognizes fewer events in the low-energy range. But the number of counts lost from the background is not proportional to the number lost from the sample.

Users of liquid-scintillation counting should be aware of this correlation and should explore it for their counting systems.

Background and Counting Efficiency of C^{14}-Spiked Tissue Samples

Sample	*Background (cpm)*	*Efficiency (%)*
Blood (100 λ)	15	0.8
Blood (20 λ)	28	12.2
Spleen	28	13.5
Kidney	29	14.3
Liver	31	14.0
Brain	41	29.3
Plasma (100 λ)	43	31.2
Solvent alone	51	33.0

Our Experiment

We have made measurements that show the correlation between background and efficiency as part of a gross metabolic study of a C^{14}-labeled drug in rats. Our suspension liquid scintillation counting had widely varying counting efficiencies from use of differently colored tissue samples. A Los Alamos fast coincidence instrument was adjusted to give ~33% efficiency with a solution containing 2 ml of absolute ethanol, 4.5 gm of polystyrene, 90 mg of *p*-terphenyl, 9 mg of POPOP and enough toluene to yield 20 ml of solution. A series of counting samples containing about 100 mg of nonradioactive tissues and body fluids were then counted to obtain background numbers with ±5% counting precision. Following this they were spiked with a C^{14} internal-standard (*1*) and counted to calibrate the counting efficiency of each sample. The results are shown in the figure and table.

Sample preparation was accomplished in the following manner. A male Sprague-Dawley rat weighing 244 gm was killed with ether, and the organs were removed. The organs were then frozen in liquid nitrogen and pulverized with a hammer (to ensure the aliquot taken was a representative part of the whole). Approximately 100 mg (±10 mg) of the tissue was homogenized in a hand homogenizer and this homogenate was transferred to 10-dram counting vials using 2 ml of absolute ethanol. To this was added 18 ml of the stock scintillation solution.

In routine practice, samples were counted and then calibrated for C^{14} detection efficiency with the internal-standard. The background numbers to be subtracted from the gross sample counts were then inferred from the figure.

* * *

Floyd R. Domer (author) was a visiting graduate student at Los Alamos from the Department of Pharmacology, School of Medicine, Tulane University, New Orleans, La., working on his Ph.D. thesis. *The work was performed under the auspices of the U. S. Atomic Energy Commission.*

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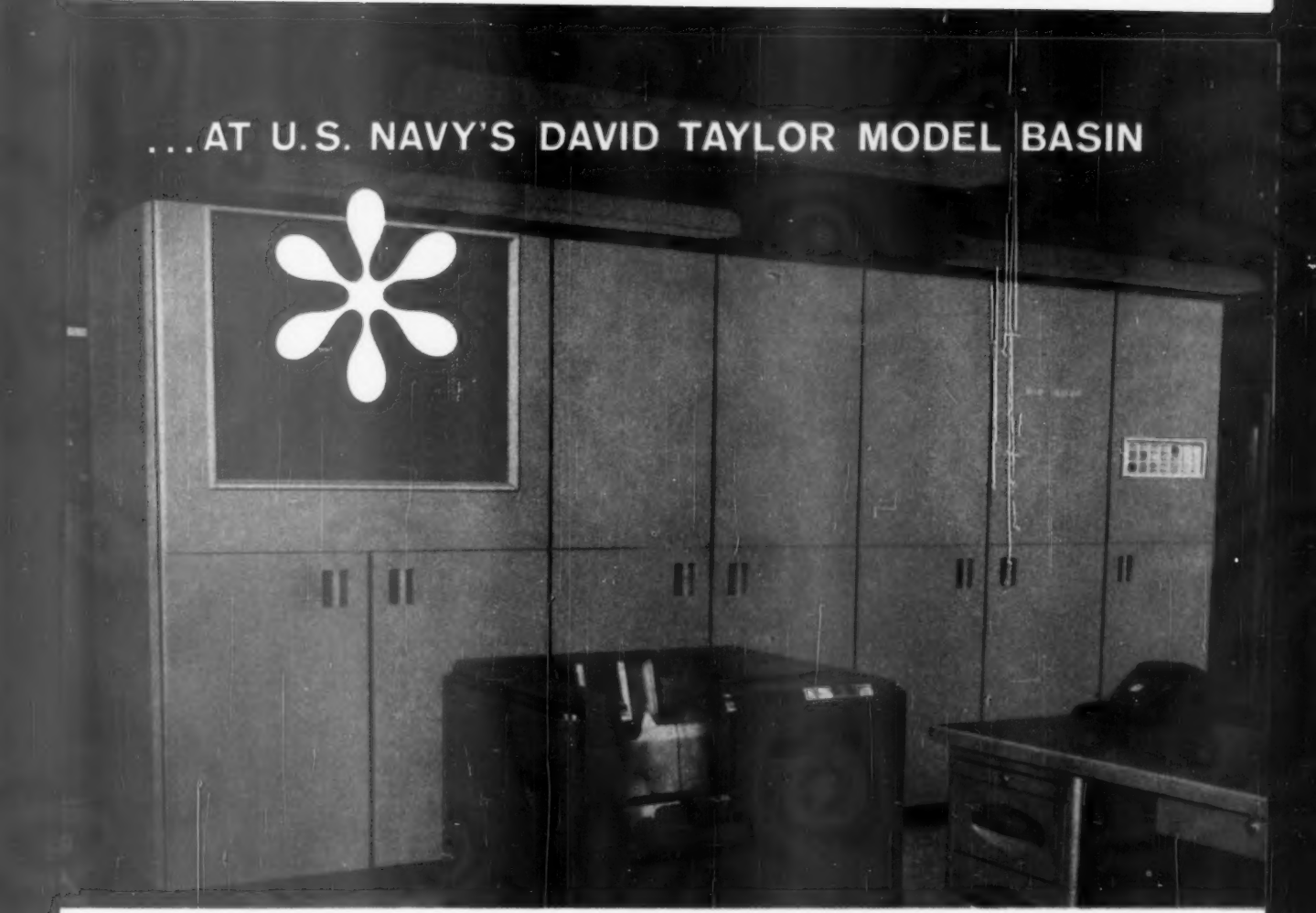

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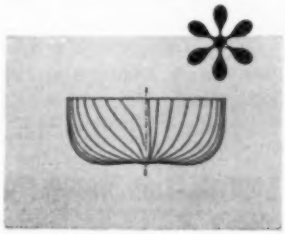

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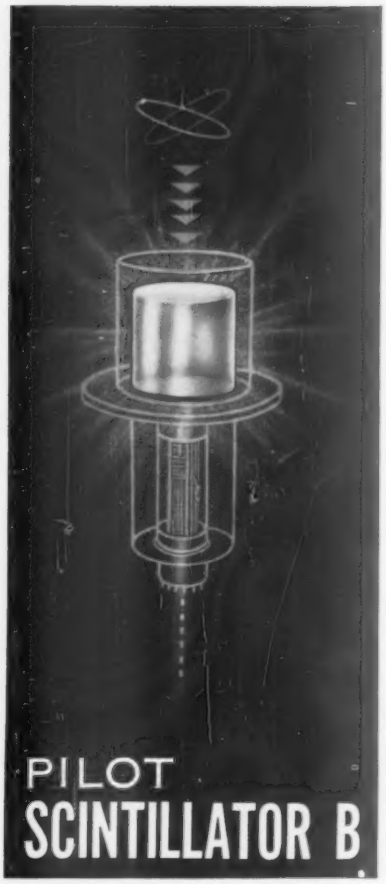

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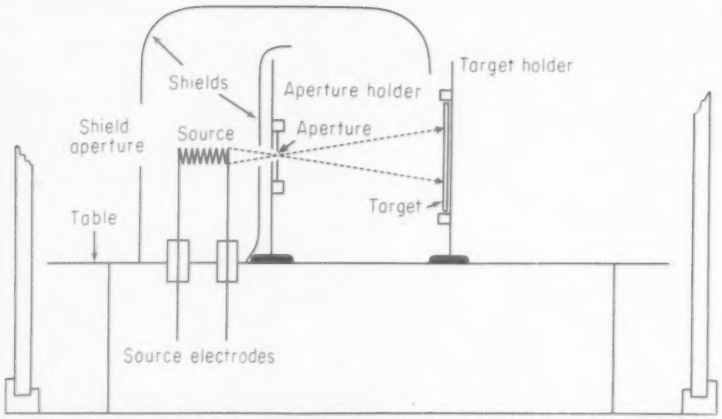


FIG. 1. **VACUUM-DISTILLATION CAMERA** modified for radioactive source. Shields prevent radioactive contamination of camera surfaces

A Vacuum Distillation Camera Using Radioactive-Metal Source

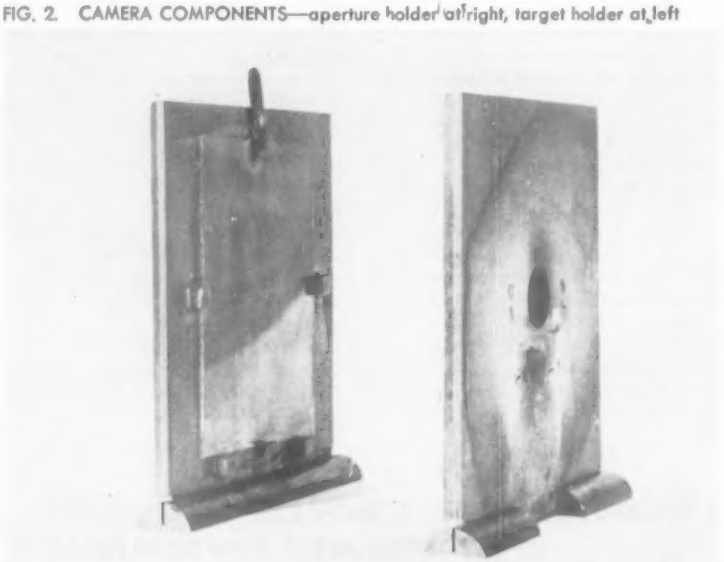
By **LUTHER E. PREUSS**
Department of Physics
Edsel B. Ford Institute for Medical Research
Detroit, Michigan

By using a radioactive metal for the source of a vacuum-distillation camera of the pinhole type and then making an autoradiogram of the target image, smaller sources and more tenuous images can be studied.

A vacuum-distillation camera is used to investigate the properties of the metal source—e.g., whether it is a true point source, as well as the amount of creep and of elastic scatter of the distilling metal atoms.

When the camera is placed in juxtaposition, in vacuo, with a high-temperature metal-distillation source, it produces an image of the evaporation geometry by condensing the evaporant on an image plate. When the distilling source is charged with a radioactive material, a radioactive image will condense on the target plate. For very large distillations, the condensed-metal image is used directly. However, the radioactive technique permits the study of distillations of about a milligram of charge.

FIG. 2. **CAMERA COMPONENTS**—aperture holder at right, target holder at left



The schematic for such a distillation camera, altered for radioactive-metal evaporation, is shown in Fig. 1. The small, removable aperture is positioned with a frame in the holder. Both the aperture and target holders are positioned on a horizontal calibrated evaporation table. The source electrodes are brought through the floor of this plate.

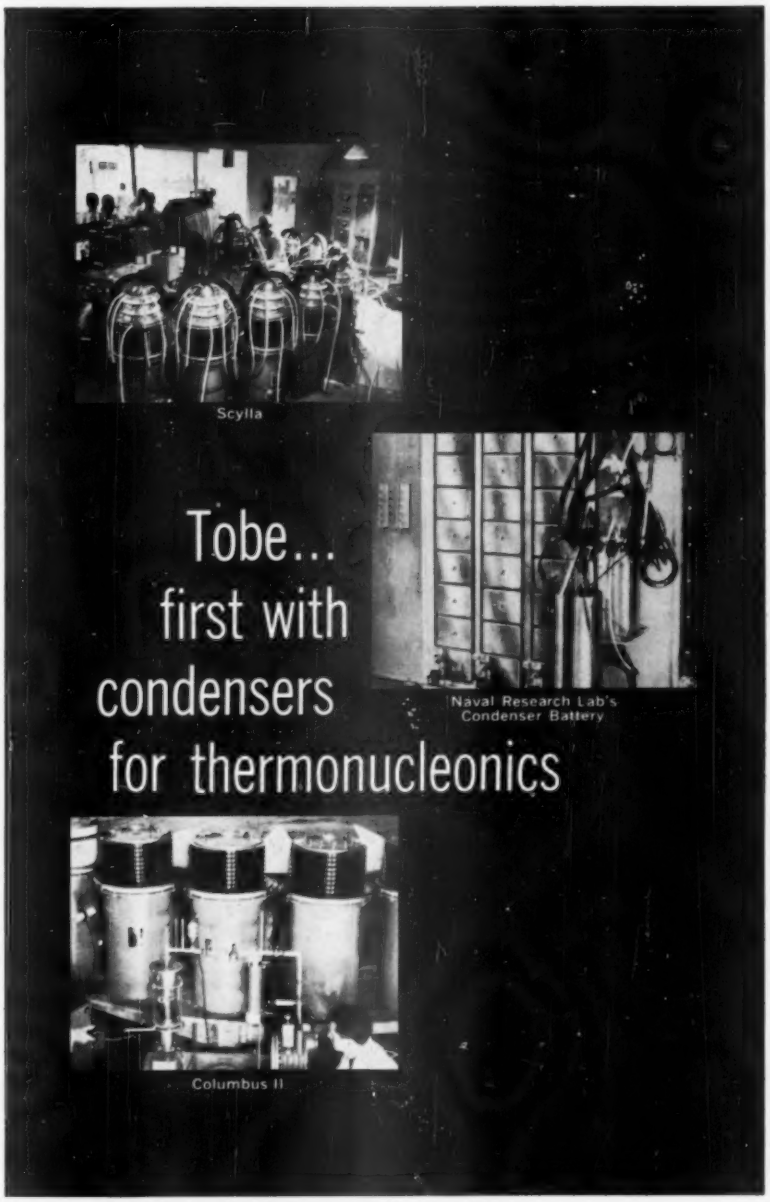
The aluminum-foil hood prevents contamination of the camera surfaces and cuts down on radiation heating of the target surface. The shield opening provides for observation and pyrometry measurement of source S. A second shield protects the surface of the aperture holder from contamination. Shields may be replaced after each evaporation. The aperture and target-plate holders, removed from the vacuum system, are shown in Fig. 2. The aperture plate exhibits some contamination on its front surface. This is caused by metals with low sticking coefficients and occurs despite the anticontamination shield.

An illustration of the image production possible with this system is given in Fig. 3.

FIG. 3. TUNGSTEN-HELIX IMAGE (20-mil diameter) from which radiogold (Au^{195}) has been distilled. Temperature of evaporation was ~1,400° C. Target activity was ~0.01 mc/mg; emulsion was Kodak medium lantern slide with exposure time of 10 days

* * *

The autoradiogram of Fig. 3 was prepared with the technical assistance of Mrs. C. Anthony; the illustrations were prepared with the aid of Mr. T. Keiser and Miss H. Horne. Their assistance is gratefully acknowledged.



Of particular interest to the thousands of international visitors to the historic Geneva Atoms-For-Peace Conference, was the display of thermonuclear fusion research equipment which the U.S. Government set up. Significantly, several of these devices use Tobe low-inductance condensers. Three of the machines are shown here.

Even now — long after the conference — inquiries and orders are being received from every corner of the globe. The postmarks read like a roll call at the United Nations: Great Britain, Japan, Italy, U.S.S.R., France, Brazil, The Netherlands, Sweden and many others.

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SNAP-II Reactor Makes Debut

The first venture of fission power into space (see Fig. 1) will be made by a 220-lb thermal reactor with a core about the size of a gallon jug. SNAP-II, one of a family of "Systems for Nuclear Auxiliary Power" under development for space vehicles, is the first of the systems to employ a fission reactor as an energy source (as opposed to radioisotopes).

Aside from its very small size (the core volume is 0.3 ft^3), the SNAP-II reactor design appears straightforward (see Figs. 2 and 3). The core is a hexagonal array of 61 cylindrical elements that delivers 50 kw(th) to a liquid sodium coolant. The fuel elements are Zr H–U^{235} and are 10 in. long and 1 in. in diameter. The sodium enters the core at 1,000° F and exits at 1,200° F, carrying the heat to a mercury boiler, which drives a miniature mercury-vapor turbogenerator. Net electrical output is 3 kw, which gives an over-all energy-conversion efficiency of 6%. By power-reactor standards, the core power density (170 kw/ft^3) is not unusual—Fermi, for instance, will run at an average 260 kw/ft^3.

Atomics International has announced the successful full-power operation of the land-based test core of the SNAP-II reactor (see Fig. 3) on Nov. 4. The mercury-vapor turbine system has, independently, been tested out by Thompson Ramo Wooldridge. The next step is to put these and the remaining components together in a prototype test of the complete unit. Within a year SNAP-II's should be waiting on the shelf ready to power the new larger satellites now being planned and, eventually, the vehicles that will explore outer space.

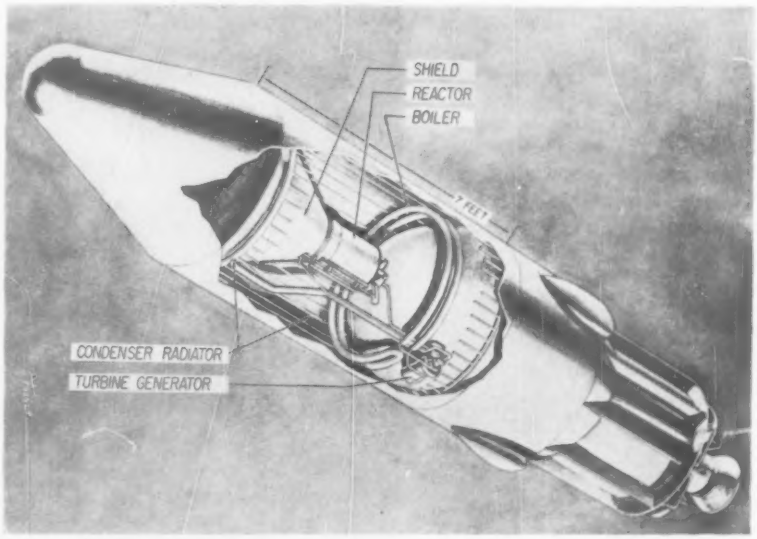


FIG. 1. SNAP-II POWER UNIT will supply auxiliary power to space ships from tiny sodium-cooled thermal reactor weighing about 600 lb total (including 400 lb of shielding). Reactor would be turned on remotely after vehicle has entered long-lived orbit or escaped into space and would supply continuous 3 kw(e) for year or longer

FIG. 2. CONCEPTUAL CUTAWAY shows hexagonal core (E) (about 10.5 in. high and 7.5 in. across) surrounded by Be reflector (D) on bottom and sides and radiation shield (B) on top. Control drives (A) rotate control drums (H), replacing portion of reflector with poison section. Sodium coolant enters at (F) and exits at (G)

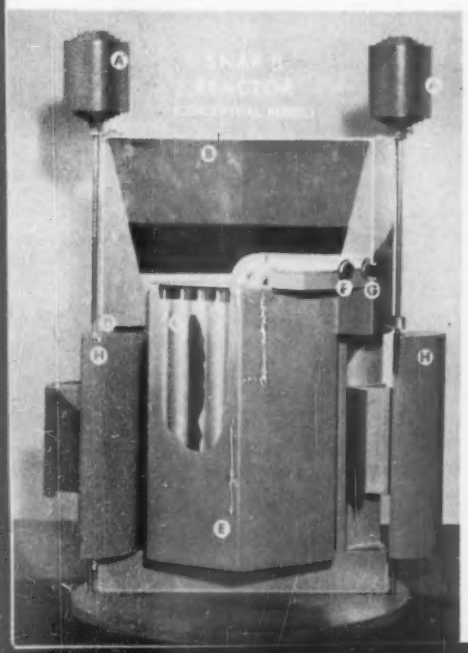
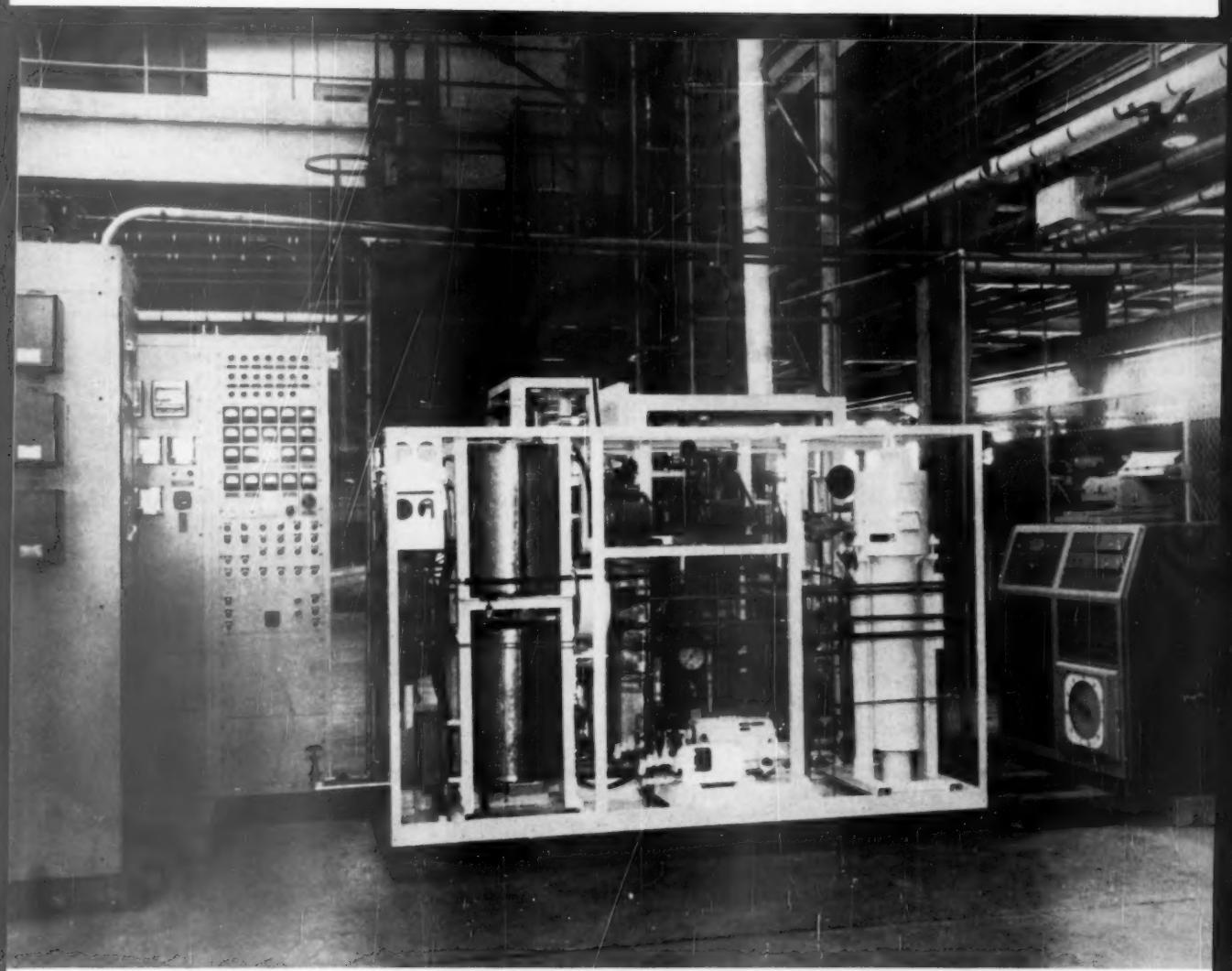


FIG. 3. TEST CORE has passed operating tests at design power and temperature. For expediency, test used moveable reflector sections (shown above) to provide control and electromagnetic pump to circulate sodium. Flight test system will go to mechanical rotary pump and reflector-drum control system described at left



General view of components. Extreme right is data logger recording thirty-two points of flow, temperature and pressure. Asbestos covered line in rear is the in-pile line. The farthest section is that which will be inserted in reactor. Unit in center contains make-up pump, vacuum pumps and neutron detector. All units are in respective positions as they will be placed on the balcony of reactor.

TEST LOOP FOR NUCLEAR REACTOR FABRICATED AT LUMMUS' ENGINEERING DEVELOPMENT CENTER

The Lummus Company Engineering Development Center, Newark, N. J., recently completed the fabrication, assembly, test operation, and dismantling of a ¾" In-pile Test Loop designed and constructed for Westinghouse Electric Corporation, Atomic Power Department, as a part of the AEC Research and Development Contract AT-(30-3)-222. This loop was built for experiments in connection with irradiation of fuel element and control rod designs for the nuclear power reactor to be installed by the Yankee Atomic Electric Company at Rowe, Massachusetts. The reactor is being designed by Westinghouse for Yankee. Upon delivery to the Materials Testing Reactor at Idaho Falls, the loop will be installed and operated to simulate actual reactor conditions on fuel element and control rod samples.

The purpose of this experiment is to study the performance of the fuel element design and its resistance to corrosion under irradiation in plant environment. It is also intended to investigate the suitability of the control rod materials. In addition to this, during the first months of operation, a water chemistry stability study is planned.

Owing to the limited space available at the Materials Testing Reactor, the entire loop was constructed in two cubicles, an instrument panel, and a motor control center. All of the components other than controls were contained in these two cubicles. Careful planning was required to insure that all equipment would fit and that there would be no piping interferences. After assembly, the loop was operated at The Lummus Company Engineering Development Center to insure meeting of engineering specifications and reliability of components. After this operation and acceptance by the customer, the cubicles, motor control centers, and instruments were individually packed and shipped to Idaho Falls for reassembly by Phillips Petroleum Company personnel, who operate the Materials Testing Reactor.

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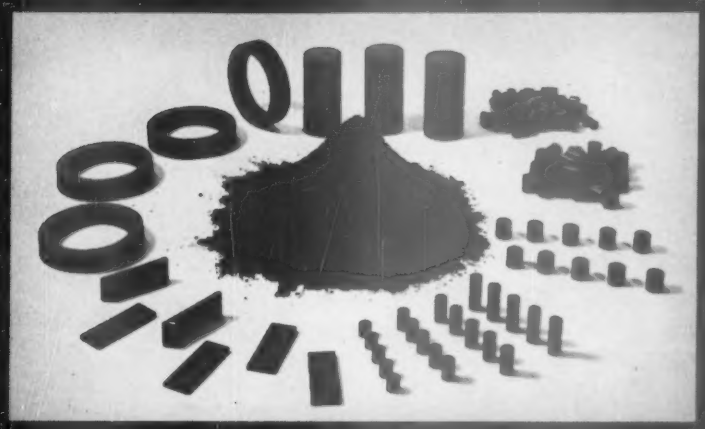

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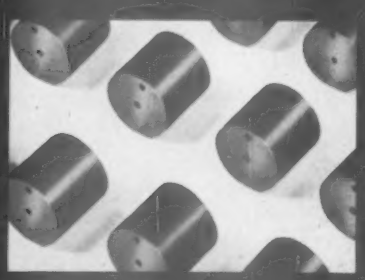


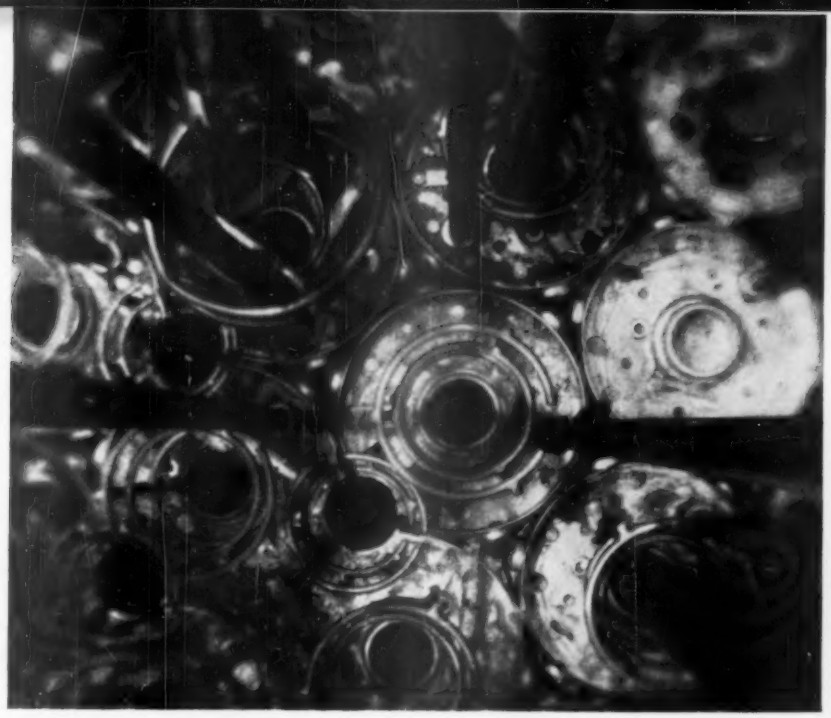
Borax IV Ran Fine On Defective Fuel

In March 1958, Borax IV ran at ⅓ full power for two days with over 30% of its fuel elements ruptured. Although this was long enough for the bulk of the escaping fission-product contamination to reach equilibrium concentration in the system, Argonne personnel* found the increases in radiation levels encouragingly low—factors of only 2–4 over normal operation in many parts of the primary system, with special points like the feedwater filter reading 100× higher. Moreover, on shutdown, all the radiation levels decayed rapidly (~30-min half-life) to the normal values of a few mr/hr. As a result, Argonne concludes that the Borax IV experiment (which was carried out impromptu after the discovery of the fuel rupture) has demonstrated that a ceramic-fueled boiling reactor can operate perfectly well for long periods of time even though its core contains a number of cladding defects.

Analysis of the effluent gases and steam-water system showed that fission-product gases accounted for most of the fission-product release. Fission products that have no fission gas as a precursor (e.g., the radioiodines or Mo^{99}) did not escape to any significant extent from Borax IV's ThO_2–U_3O_8 fuel pellets. The postoperational activity found in the turbine and condenser was mostly Ba^{140}-La^{140}, Sr^{90}-Y^{90}, Sr^{89} and Cs^{137}—all decay products of short-lived fission gases.

The apparent cause of the fuel failure was the collapse under 300 psi design pressure of the aluminum-tube fuel cladding. Metallurgical examination of two defective elements showed that the thin pellet tubes that make up the Borax IV plates had collapsed in the void region above the pellets, producing numerous fine pinhole cracks. Of the 69 elements in the reactor, 22 appear to have failed in this way to a greater or lesser degree. At 2.4 Mw these defects released about 6,000 curies/day of Xe^{138} into the system; the corresponding rate for the EBWR defect experiment at 20 Mw was 1–1.5 curies/day. More detail on the fuel failure will be given in a forthcoming Argonne report, Examination of Borax IV defective fuel plates, by C. F. Reinke.

* R. F. S. Robertson and V. C. Hall, Jr., Fuel defect test—Borax IV, ANL-5862 (Oct. '59).



POST MORTEM VIEW of top of SRE core shows encrustation on snorkle tube vent (vertical tube) from center moderator can. Loose fuel slugs are strewn about on tops of other cans (top center). At time of picture core temperature was 325° F and radiation field below top shield 100 r/hr

Coolant Block Damages SRE Fuel

By ROBERT W. DICKINSON
Atomics International, Canoga Park, California

A leak of organic material from an auxilary cooling system into SRE's primary loop has subjected the SRE fuel to a much severer trial than anyone had bargained for. With the flow partially blocked in several channels by deposition of the material, temperatures got high enough to cause the stainless-steel clad to alloy with the uranium-metal fuel and, finally, to separate near the bottom end (NU, Dec. '59, 23). Here's the sequence of events as they appeared to SRE personnel operating the reactor. —Ed.

On July 27, 1959, the Sodium Reactor Experiment (SRE) was shut down to determine, through viewing of fuel elements by a closed-circuit television system installed in the fuel cask, if there were obstructions that could explain rather wide temperature variations between fuel channels, which were preventing full-power operation of the reactor. As a result of this examination, twelve fuel elements out of the 43 fuel elements installed were discovered to be damaged. Preparations are now in progress to put SRE back in operation on a new second core of SS-clad Th-U^{235} metal fuel around the middle of April. Individual trials of UC elements (which will probably make up the third core) will begin late in summer.

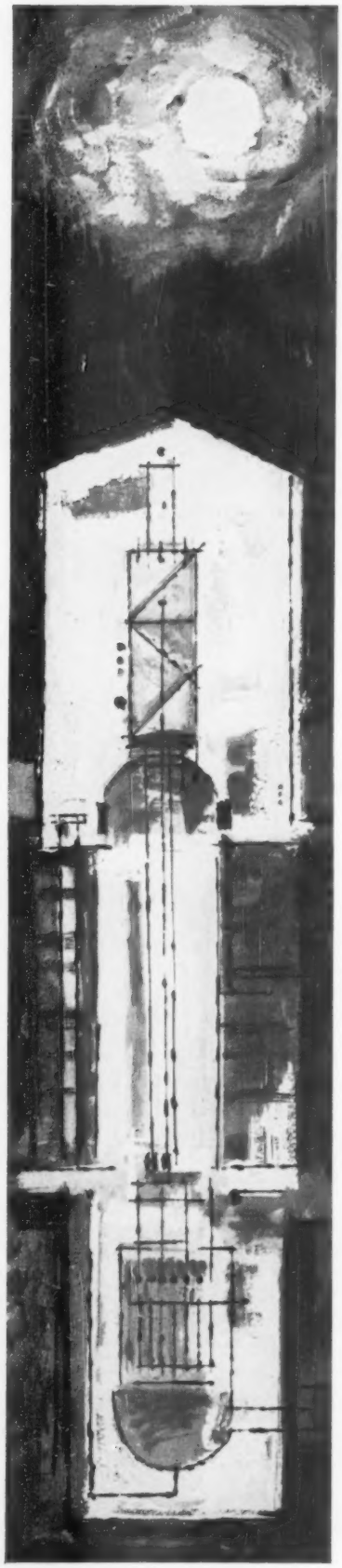
Tetralin Leakage

The SRE had previously run a total of 2,409 Mwd; during this time it generated over 15×10^6 kwh of electricity in a series of operations designed to irradiate the alpha-rolled, beta-heat-treated unalloyed uranium which comprised the first core. The length of these power runs was determined by examining the fuel elements both destructively and nondestructively, for evidence of radiation induced swelling, and had varied from 150 to 300-Mwd fuel exposure per run. During the shutdown period preceding the power run of interest (Run No. 14) modifications had been made to the main primary system; the most significant of these was the replacement of the tetralin-cooled shaft freeze seal on the main primary pump. A NaK-cooled freeze seal was substituted.

This alteration, long contemplated, was effected because, during the preceding power run (No. 13) there had been evidence of tetralin leakage into the primary sodium system. Tetralin leakage was apparent from a characteristic odor in the vicinity of the pump, and, after shutdown, the appearance of napthalene and other decomposition products of tetralin in a vapor cloud over the reactor's top sodium pool. This vapor cloud, which was visible through a glass window inserted in the top shield after shutdown, was purged by sweeping with inert gas; approximately a pint of tetralin, napthalene, and other decomposition products were condensed out of the purged gas. After stripping hydrocarbons from the core with dry nitrogen gas introduced at the bottom of the core, no detectable hydrocarbons could be observed in the core cover gas. Some 4×10^5 ft^3 of nitrogen were employed; the stripping operation was carried out with sodium at the normal shutdown temperature of about 375° F

Although some concern was felt

(*Continued on p. 109*)



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This article starts on page 107

concerning the presence of tetralin and its decomposition products in the primary system, previous experiments* had indicated the primary product would be amorphous carbon. Although carbon is a potential contributor to system carburization, it was not considered to be a short-term hazard. Examination of fuel had indicated that radiation-induced swelling was already sufficient to require removal of the fuel following power Run No. 14, and the effects of carbon on the thin-walled cladding were not significant for this period of time.

Temperature Maldistribution

Upon start up of the reactor in a normal fashion, wide variations in temperature from individual fuel channels, as monitored by thermo-couples on the fuel hanger rods, were indicated. Analysis of temperature variations throughout the reactor indicated that a condition of unequal flow through fuel channels existed.

Similar temperature spreads had appeared following a shutdown in December 1958 during which system modifications had been performed and considerable oxygen had entered the system. At that time, clean up of the system using cold traps and increasing the reactor inlet temperature to 600° F had reduced temperature spreads to a normal pattern; following this full power operations with sodium-coolant temperatures as high as 1,060° F were performed with no indication of anomalous behavior.

The same procedure was followed in July, as oxygen had again been introduced into the primary system by pump alterations. This time, however, the temperature spreads were more persistent. The reactor was operated at power levels of 0.5–3 Mw, controlling on a maximum temperature differential between fuel-channel outlet and adjacent moderator-can coolant passages of 100° F. This temperature differential was established by stress considerations relative to the top head of the zirconium-clad graphite logs that form the SRE moderator. Increasing the inlet temperature to the reactor, by operating on an air-blast heat exchanger instead of the steam generator, did not appear to be helpful in reducing the temperature spread, as had been the case during December.

* NAA-SR-2178

In addition, some anomalies in reactivity occurred which were attributed at the time to the passage of gas bubbles through the core, postulated to have been due to the organic decomposition products. One of these reactivity transients prompted a manual scram. Reconstruction of control-rod positions during the period of operation also indicates a small reactivity decrease, occurring from day to day in sufficiently small amounts as to not be readily apparent. The cause of this gradual decrease in reactivity has not been determined at this date; neither have the reactivity perturbations experienced during operation been unequivocably explained.

During two weeks of this low power operation it was noticed that if some of the fuel elements were moved slightly, the exit coolant temperature decreased significantly. A possible explanation of this phenomenon was considered to be the dislodging of oxide (and possibly carbon) particles which had collected on the orifice plates installed at the bottom of the fuel elements. Accordingly, it was decided to shut the reactor down and inspect representative elements, to determine the nature of these deposits if in fact they did exist.

Fuel-Element Inspection

On July 27 the reactor was shut down and a fuel element withdrawn into the fuel handling cask, into which a closed circuit television camera had been incorporated. The first two elements so inspected showed no anomalies. The third element inspected, however, appeared to have a crack in the cladding, although the element itself was intact. It was then decided to examine a fourth element which, when removed, showed that the bottom third of the element, including the bottom hardware, was missing. The separation of the seven rods, which make up the element bundle was approximately at the same level and was apparently complete, even including the spiral wire wrap attached to the top and bottom of the fuel rod.

A program for inspecting the remaining fuel elements was immediately initiated. As damaged elements were discovered, they were removed from the reactor and placed in storage. Ten additional damaged fuel elements out of a total of 41 inspected were discovered by this means. Two additional elements appear to be securely lodged in their process channels and are therefore assumed to be damaged.

(Continued on p. 110)

Senior Metallurgists, Physical Chemists and Engineers

Reactor Materials: Research involves investigation and analysis of mechanical and physical properties of metallic alloys and inter-metallic compounds. Materials are to be used in power reactors for fuel, and fuel cladding, moderators, control rods, and structural members. Studies will include analysis of materials after exposure to high temperatures and radiation fields.

Fuel Element Engineering: Responsible for the complete analysis and design of fuel elements. This includes nuclear, thermal, material, mechanical and cost analyses. Should be familiar with fuel life determination methods and reprocessing techniques.

Fuel Fabrication: Activities will include development fabrication of materials and fuel elements, for both plate and rod forms and complex assemblies. A knowledge of non-destructive testing methods is essential, in addition to familiarity with a wide range of material processing and fabrication techniques.

Irradiation Experimentation and Hot Lab Evaluation: Senior Research Engineers and Physicists are required to design and conduct irradiation experiments on developmental materials including reactor fuels. The individuals must be familiar with a wide range of radiation and temperature conditions. Experimental conditions will include the simulation of conditions expected in full scale power reactors. Also senior personnel are needed to develop equipment and techniques required for the post-irradiation testing and evaluation of these experiments.

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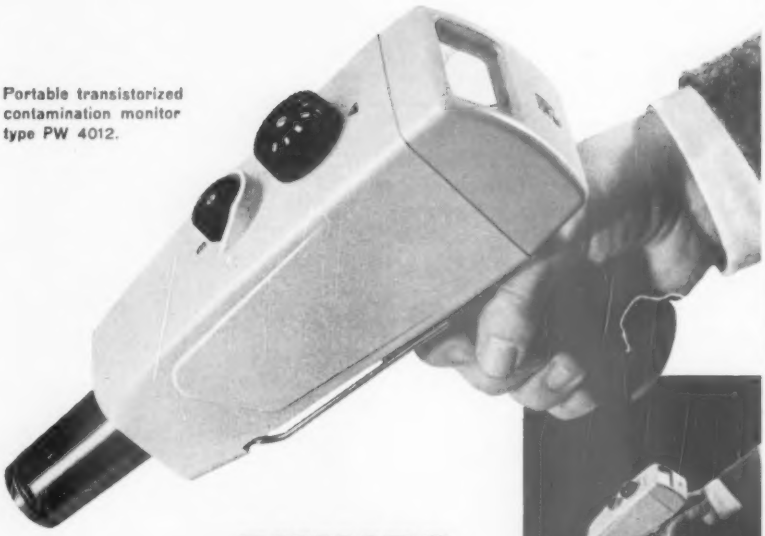

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NUCLEAR ENGINEERING

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The original fuel cask does not contain a provision for handling fuel elements in which wires and hardware are widely spread out; the chain hoist mechanism became fouled by projecting portions of the 34th element removed. After several days of manipulation in the cask containing this damaged fuel element (during the course of which at least three fuel slugs and numerous pieces of cladding were disloged into a shielded cavity located below the cask) further efforts to free the cask operating mechanism were suspended. Assembly of a second cask, originally designed for handling moderator cans and/or fuel elements, was commenced; this cask was used to remove the remaining elements, except for the two apparently lodged in the core.

Causes of Damage

Examination of the fuel slugs recovered from the handling cask indicated that cladding failure apparently was responsible for the separation of the fuel element. Sections of .010 in. stainless-steel cladding adhered to the slugs; the intimate contact suggested that an iron-eutectic had formed. Chemical analysis of sections of cladding and wire wrap recovered confirmed this indication; uranium contents as high as 10% were determined to be present in cladding sections analyzed. It is postulated that overheating had occurred in at least some of the channels, permitting fuel surface temperature to rise at least to the 1,340° F necessary to form the Fe-U eutectic.

The thermocouples that monitor exit-flow temperatures for each channel at no time read higher than 900° F and thus gave no clue to the excessive surface temperatures. Apparently, under the restricted flow conditions (which caused the hot channels), the thermocouple readings were thrown off by thermal contact with the sodium pool above the core.

Altogether, an estimated 5,000–10,000 curies was released at the time of the damage, 80% of which was less than one day in half-life.

An examination of the circumstances surrounding fuel-element damage was commenced immediately on discovery; deposits of a viscous, tar like substance were identified on hot-cell examination of a damaged fuel element. Deposits were observed on the top spider which supports the fuel rods and on the moderator can hold-down tube which

is installed immediately above the fuel elements. Samples of this deposit were analyzed; they proved to be carbonaceous materials containing varying amounts of hydrogen. These were apparently decomposition products of tetralin. It is reasonable to assume that such carbonaceous material has deposited at points of flow restriction and may be the primary cause of decreased coolant flow in those channels which contain damaged fuel elements.

The point of tetralin entry into the system was determined to be the main primary-coolant-pump-shaft freeze seal. A metal-sprayed layer in the vicinity of the tetralin-cooled shaft freeze seal, originally put on to build up shaft diameter where excessive wear had once occurred on the pump shaft, had apparently come loose and abraded the shaft-seal cooling chamber to a point where tetralin was admitted directly into the sodium stream. No excessive tetralin consumption had been observed; there are constant losses of tetralin due to evaporation in the cooling tower and occasional piping leaks outside the reactor area. Examination of tetralin make-up did not indicate excessive consumption during the preceding power runs; it is believed that no more than two barrels of tetralin were introduced into the system, and quite probably considerably less.

Future Plans

Development of fishing tools based on possible conditions in the lower end of the fuel channels containing damaged elements was initiated immediately. It is known that the bottom hardware of the fuel element would come to rest, after a drop of some 10 in. from its normal position, against the stainless-steel pedestal on which the moderator can is mounted. Therefore, the remaining sections of damaged fuel elements would not fall into the bottom plenum below the core. Grappling tools that attempt to engage the hardware below the fuel rods, and bring the damaged section of fuel element up through the fuel channel as a unit were devised and tested in full scale mock-ups. The degree of fuel swelling, deposits of carbonaceous material, and degree of damage to the bottom section of the element, is not known at this time; the efficacy of recovery procedures in an actual channel is yet to be demonstrated. It is, however, expected that each channel will present somewhat of a different problem, the magnitude of which will be at least partially established by observation with a borescope specifically constructed for in-core examination. This borescope contains its own illumination and cooling system, and is capable of being inserted completely through the core if necessary. It also contains provisions for inspecting the under side of the grid plate on which the core is mounted.

Several facets of reactor operation must be covered prior to restoration of the SRE to full power operation with its second core loading of thorium-uranium fuel:

- First, of course, is the removal of fuel, its examination, and verification of the cause of damage.
- Second is an inspection of the core channels by borescope for obvious evidence of damage to moderator cans.
- Third, it is planned to survey the core using the neutron source in a fuel channel and observing this source with detectors in adjacent channels to determine, by neutron absorption, if sodium has been introduced into any of the graphite moderator logs.
- Fourth, any carbonaceous material remaining in the system, particularly in the vicinity of the heat exchangers, must be removed as completely as possible. Numerous schemes have been proposed; these will depend on observations of the nature of the deposits. It is currently planned to examine visually the intermediate heat-exchanger primary (tube) side, inasmuch as this exchanger showed a loss of heat-transfer capacity toward the end of the power run previous to the one during which fuel element damage was discovered.
- Fifth, the new fuel elements are being modified to contain thermocouples further down in the element, where they will be less affected by sodium-pool temperature. Additional fuel elements will be provided with thermocouples.
- Sixth, revision of the coolant systems to remove what is now considered the underlying cause of fuel element damage: introduction of carbonaceous material. Coolant systems which do not involve materials incompatible with sodium will be installed.

Upon completion of these steps, SRE will be returned to power with a loading of thorium-uranium fuel, to continue to provide high-temperature irradiation of reactor fuels and further information on high-performance liquid-metal-cooled reactor systems.

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Are Irradiated Foods Harmful?

By HERMAN F. KRAYBILL

There is no evidence that there is any toxicity in irradiated foods for either man or animals. The false conclusion that there is such evidence has arisen from misleading information published by the press relative to biological response of experimental animals fed with irradiated foods.

On the Record

Since the inauguration of the Army program on Radiation Preservation of Foods, annual reports to Congress have consistently stated that when irradiated foods are fed to experimental animals or man, there is no observed toxicity (*1*). Earlier this year a Summary Report presented by the Office of the Surgeon General restated that there was no direct evidence of any nutritional or pathological toxic phenomena prevailing when irradiated foods are consumed by animals or man (*2*).

More recently representatives of the office of the Surgeon General stated that no ill effects on growth, reproduction, and longevity could be traced to irradiated food (*3, 4*). There are many publications in the scientific literature that document the fact that thus far no toxicity has been observed (*5, 6*).

On the other hand, recent newspaper stories connote to the unwary that indeed irradiated foods fed to animals have given rise to (a) bleeding disorders in rats (hemorrhagic diathesis), (b) blindness in rats, (c) heart defect or auricular rupture in mice, and (d) sterility or infertility in dogs.

Experimental findings related to these effects but by no means connoting such conclusions have been available in reports for some time (*7*). Knowledge of all this prevailed when official reports indicated that no toxicity was evident in the ingestion of irradiated foods.

Bleeding in Rats

As early as 1955 it was observed that feeding a specific irradiated diet produced an increased blood-clotting time in chicks (*8*). Although ionizing radiation had some destructive effect on vitamin K (anti-hemorrhagic factor), the addition of high-vitamin-K components such as alfalfa or spinach prevented the alteration in clotting time.

Others observed a hemorrhagic diathesis in rats fed irradiated beef (35% solids) in combination with a nutritionally adequate synthetic ration (*9*). The syndrome was more predominant in male rats. The diet was not supplemented with menadione (vitamin K) since it has been generally believed that the rat is capable of synthesizing vitamin K in the gastrointestinal tract. More recently several investigators have shown that the mere addition of soybean protein to a synthetic ration will induce bleeding in rats (*10*).

Occurrence of bleeding can be attributed to either destruction of vitamin K or failure to synthesize the vitamin by the animal under certain conditions. The exact mechanism is not fully understood at the present time. However, the administration of vitamin K will correct the condition. It was first thought that oxidized or degradative products formed in the irradiation of beef caused the destruction of vitamin K (*5*). However, it has since been shown that under similar conditions the feeding of cooked meat or pork at 35% solids level in diet, along with synthetic ration will also induce the hemorrhagic diathesis (*5*). Heated or oxidized fats have similar effects (*2*). For sometime therefore the effect has been ascribed to an artifact in the diet. It is doubtful that these findings have any parallel in human nutrition.

This phenomenon is important in our understanding of vitamin K metabolism and demonstrates that radiation or heat processing can produce nutritional deficiencies. But this has no toxicological significance.

When a diet is not supplemented with vitamin K, a synthetic ration to which cooked meats, heated fats or even soybean protein are added can induce hemorrhage. Addition of vitamin K or a diet containing a wide spectrum of vitamin-K-containing foods will prevent the hemorrhagic syndrome. Thus the observed effects are definitely nutritional and there is no toxicological effect that can be ascribed to the feeding of irradiated beef.

Behind the Story

The Army program on irradiated foods suffered a setback in October when Richard Morse, Army chief of research and development, announced at a press conference that program promise did not match cost (NU, Nov. '59, p. 26). Objections have been raised that Morse did food irradiation a disservice in his explanation by exaggerating biological problems and leading the nontechnical press to false conclusions (NU, Dec. '59, p. 17). The author, a recognized authority on wholesomeness of irradiated foods, tells why he feels that published conclusions are not warranted by the available evidence. —*Editors*

Congenital Blindness

Richardson and his colleagues noted in 1955 that with a particular strain of rats offspring were born blind when *either* an irradiated or nonirradiated ration was fed to experimental animals (*10*). It was first observed that the incidence of congenital blindness was slightly higher in offspring from mothers receiving the irradiated diet. However, in repeat experiments it was observed that congenital blindness in offspring was slightly less from mothres receiving an irradiated synthetic diet than from those receiving the nonirradiated control diet.

Therefore it appears that the incidence of blindness is not associated with irradiation of the food. The incidence of blindness has been low in every case, and blindness has been observed in other completely unrelated experimental work using this strain of rats.

The data from these studies establishes that the irradiated foods are equal in nutritive value to nonirradiated foods and that they are not toxic.

Sterility in Dogs

In 1958 McCay observed that some female beagles failed to conceive in a group that was fed 35% solids of irradi-

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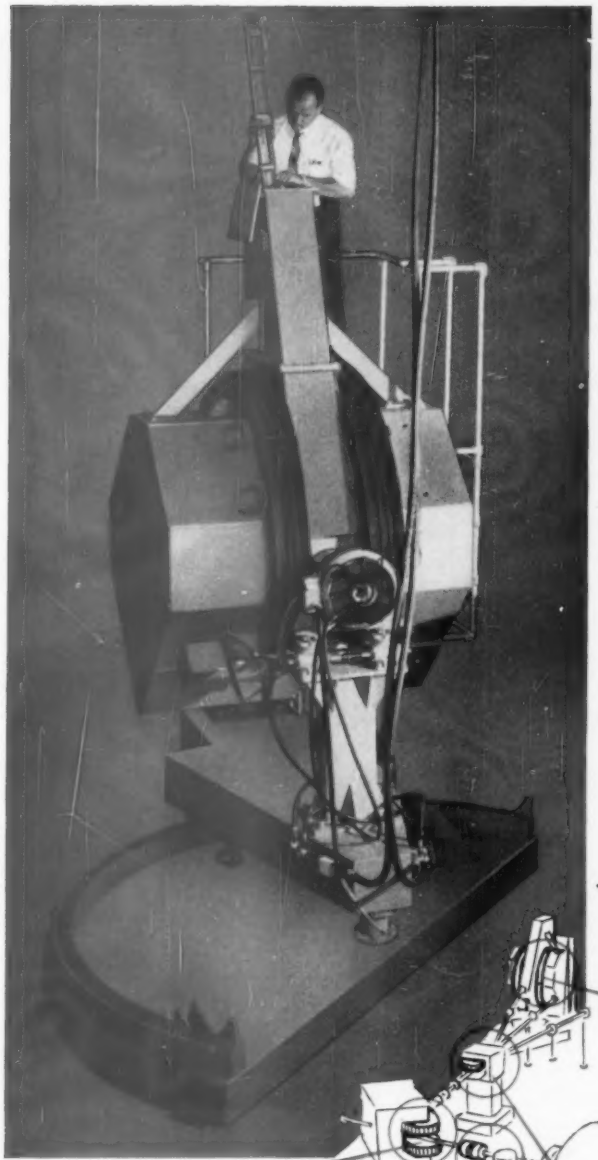

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*For further technical reference, see H.A. Enge, RSI **29**, 885 (1958)

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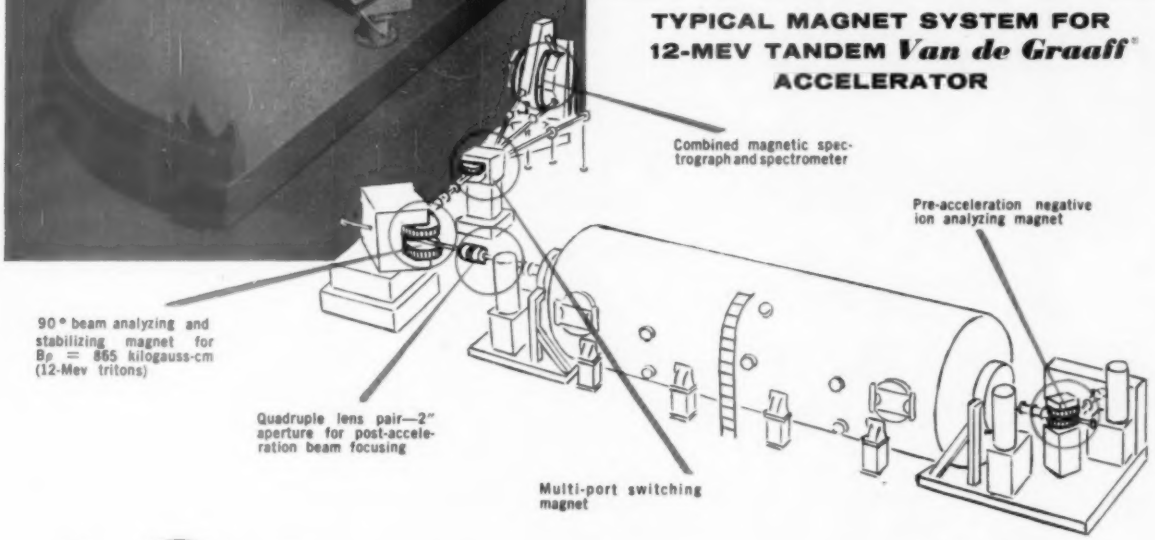
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This article starts on page 112

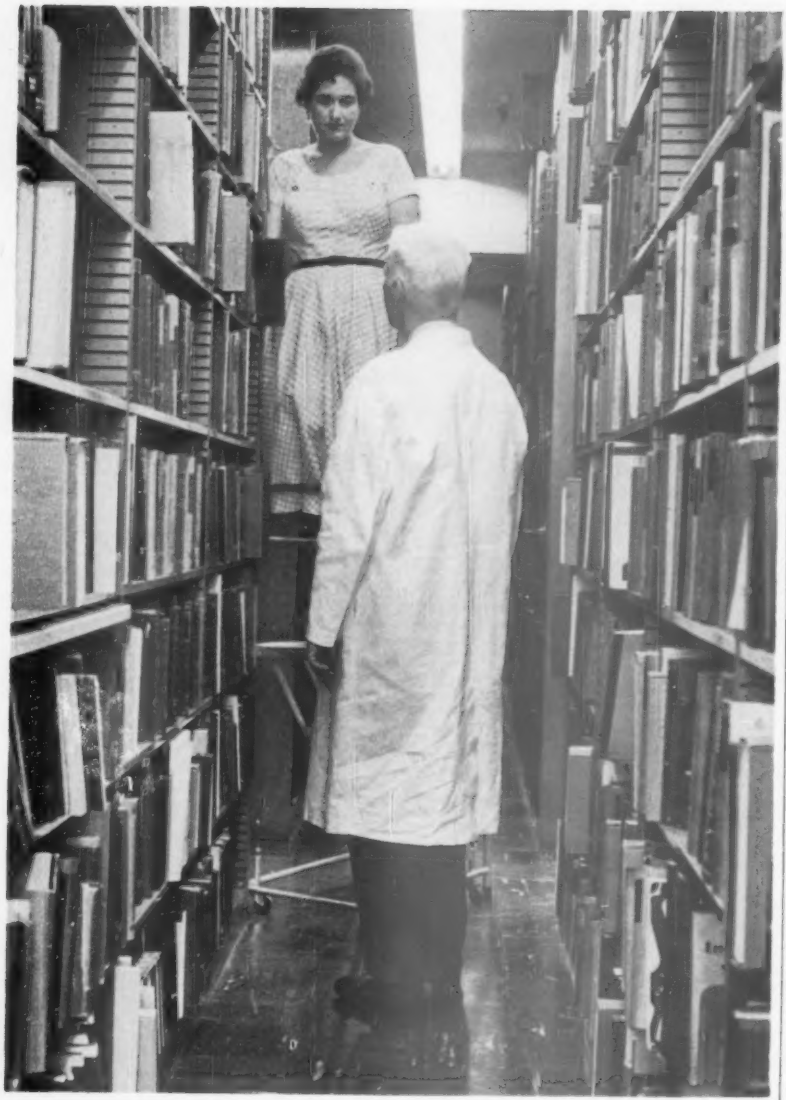
ated beef (*11*). Similarly a few dogs fed irradiated egg solids had been noted previously by other investigators to exhibit this same phenomenon (*12*). These findings have not been consistent since previous experiments and subsequent feeding trials with dogs fed irradiated meats or eggs have failed to produce infertility (*7, 11*).

Seven other investigators feeding a wide selection of foods, irradiated and nonirradiated, to approximately one hundred dogs have failed to confirm these unique findings thus far (*7*). Considerable attention has been given to the administration of fat-soluble vitamins, particularly vitamins A, E and K when irradiated foods are tested. In the beef-feeding experiments the fat-soluble vitamin supplement was given only once a month to the dogs. It is probable that significant vitamin E destruction—repeatedly demonstrated in rats—may play a significant role in these few cases of reproductive failure. Partial correction of the reproductive failure in dogs fed irradiated dried whole eggs has been brought about by supplementing the diet with biotin, again suggesting a vitamin-deficiency relationship (*12*).

Nutritional and genetic parameters doubtless have some bearing on these observations. None of the investigators have ascribed these effects to the general feeding of irradiated foods because these results are not consistently noted and reproducible. Neither has the causative agent, if in truth there is one, been ascribed to a toxicity resulting from feeding irradiated foods. Finally, the translation of these results to human nutrition on the basis of a possible vitamin E deficiency cannot be made since the role of this vitamin in human physiology has not been established.

Heart Defect

In 1958 Monsen made the interesting observation that some mice on an irradiated ration developed a rupture of the auricle (*13*). This finding seemed to be quite accidental in that this lesion was produced predominantly for three months in the fall of 1958 and after that time the auricular rupture could not be duplicated in any strain of mice whether they were fed irradiated or nonirradiated foods. Neither could the omission or supplementation of vitamins to any diet or varying the



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composition of the diet shed any light as to the possibility of a causative agent in this situation. If toxic factors are present in foods it should be possible to demonstrate them in repeat experiments, analogous in design.

It is impossible to point with certainty to the presence of all important vitamins in the diet during the three-month period. A vitamin antagonist may have been present or a toxic factor may have prevailed in the basic components of the commercial synthetic ration. It is quite evident, however, that no toxicological property can be associated or related to the feeding of irradiated foods. In addition such observations have not been confirmed in the feeding of a broad spectrum of irradiated foods to hundreds of mice in the work reported by other investigators.

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Radioactive Sources Indicate Axial Position in Jet Engine

By J. F. COULTRY and H. D. BRIGGS
General Engineering Laboratory
General Electric Company
Schenectady, New York

During operation of a jet-engine turbine, thermal expansion takes place in the rotor and stator. The predictability of this expansion is complicated by such factors as the different thermal-expansion coefficients of the different materials and sharp temperature gradients. A particular problem in turbine operation is that, as the temperature increases, the rotor and stator expand in opposite directions. As indicated in Fig. 1, this causes the clearance between the rotor bucket and stator nozzle, 0.75 in. in the cold engine, to decrease in the axial direction. There is thus the hazard that these parts will rub and damage the engine.

The decision to use a radioisotope technique to study this phenomenon was based on several factors: inaccessibility of the turbine interior during operation, high temperatures, high speed of the rotor, turbine vibration and restrictions against modifying the rotating parts. In addition, radioisotopes offer the advantages of accuracy, remote control, rapid readout of data, ruggedness, simplicity and safety.

The system designed for this study is shown in Fig. 1. One radioactive source is located on the stator and the other on the rotating bucket. The source positions are picked up by the scanning scintillation probe, which is mounted on the table shown in Fig. 2. The peaks traced by the recorder (Fig. 3) indicate the source separation and thus the clearance between bucket and nozzle.

Instrumentation

The scanning unit (Fig. 2) consists of a collimated General Electric

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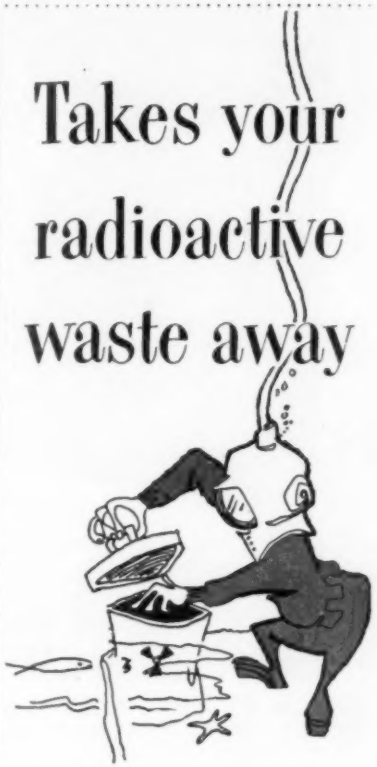

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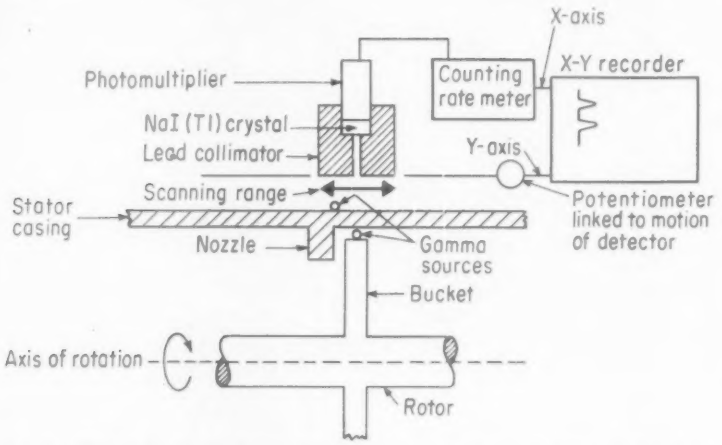

FIG. 1. MONITOR checks clearance between rotor bucket and stator nozzle of turbine by measuring separation of gamma sources

probe (RCA 5819 photomultiplier and 1 × 1½-in. NaI crystal), counting-rate meter and recorder.

The probe is mounted on a table, which scans the measurement area by means of a constant-speed, reversible motor. The motor is reversed when the table strikes limit switches at each end of its travel. The scanning rate is usually 3 min per scan. The collimater is constructed of 2 × 4 × 8-in. lead bricks, which form a $\frac{1}{16}$-in. slit to view the sources. Collimation limits the effect of background radiation and prevents interference between the two sources.

The counting-rate-meter output voltage, which is proportional to the probe output, controls the Y-axis component of the recorder tracing (Fig. 3). The X-axis component is controlled by the position of the probe; this signal is obtained from a potentiometer attached to the scanning table. When the radiation probe reaches each end of its travel and the motor reverses, a signal is sent to the recorder to identify both end stops on the tracing.

Clearance between the bucket and the stationary nozzle is measured directly from the separation of the source peaks on the recorder tracing. The end-stop signals serve as reference points from which individual movement of the bucket and stator can be determined.

A device is provided that allows the operator to reverse the scan of the probe at will. In a "near-rub" condition, where a full scan is not necessary, the operator can scan only the two source peaks, omitting the end-

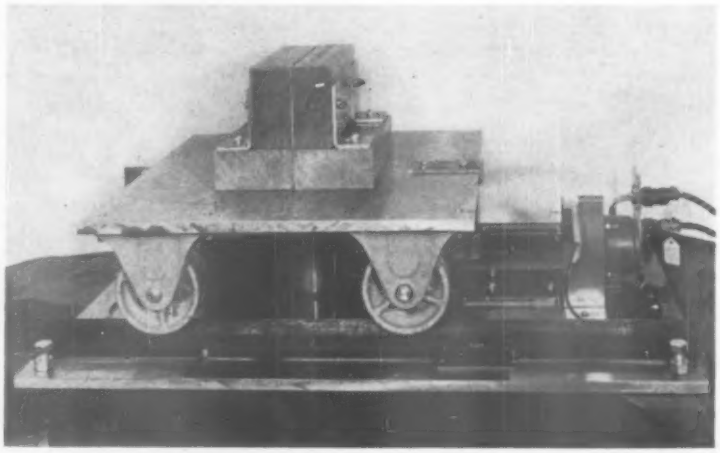

FIG. 2. SCINTILLATION PROBE is mounted on motor-driven scanning table; collimator, formed of four lead bricks, has $\frac{1}{16}$-in. slit

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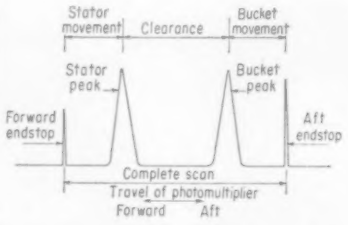

FIG. 3. RECORDER TRACE of one scan of probe shows peaks indicating positions of bucket and stator gamma sources; endstop peaks indicate ends of scan signaled by reversal of scanning-table drive motor

stop information. In this way, display time can be reduced by at least 50%.

Radioactive Sources

The stator source, a piece of radioactive cobalt wire enclosed in stainless steel, is placed in a source holder welded to the stator casing.

Attaching a source to the bucket was ruled out because of the restriction against modifying the bucket, lack of a bonding material that would stand up under severe temperature and high centrifugal force, and the contamination problem should the source be "rubbed" off during operation.

Initially, therefore, radioactivity was induced on the tip of a bucket by deuteron bombardment in a cyclotron beam. The principal activity (after an initial cooling period) was from Co^{60} produced by the reaction $Co^{59}(d,p)Co^{60}$. At least 50 microcuries was needed to produce a sufficiently strong signal outside the stator casing during rotation.

After testing several turbines, another method of placing the source on the bucket was adopted. The designers decided that a hole 0.040 in. in diameter drilled near the tip of the bucket would not affect the operating characteristics of the bucket. A piece of cobalt wire encapsulated in stainless steel is then pressed into the hole.

The source is installed late in the buildup of the turbine to cut down on the need for radiation-safety supervision. The source can be pressed out of the bucket upon completion of the test, allowing the bucket to be reused. Sources are 300–700 microcuries.

Since the position of the bucket is fixed by the rotor design, the position of the source on the bucket tip cannot be varied. Therefore, the separation of the sources must be adjusted by moving the stator source.

The optimum separation of the sources was determined by the following conditions: (1) Since the clearance of the bucket and nozzle in the cold turbine is 0.75 in., the sources must be separated by more than 0.75 in., otherwise the peaks would overlap in the "near-rub" condition. (2) Since the scanning distance of the probe is 3 in., the 1.25-in. separation permits sufficient accuracy in measuring peak movement relative to the end-stop reference peaks.

Discussion

This system has an accuracy of 1% of the full scan. Greater accuracy is attainable. However, in this application, simplicity and extreme reliability are considered of prime importance.

The simplicity permits the operator to be a person of average technical ability and no radiation technology background. Reliability is obtained in two ways: (1) Since information is taken from the peak positions, errors due to changes in counting rate are eliminated. (2) Most of the equipment consists of easily replaceable standard items.

Since the bucket (and the source) operate at various rpm's during a test, the effect of the rotational speed on the probe counting rate was investigated. At low speeds, the bucket would be at the point of measurement for longer periods but fewer times per minute than at high speeds. It was calculated and later experimentally proven that an attenuation of about 8 occurs from the "at-rest" position of the bucket to about 100 rpm. From this speed up to about 6,000 rpm, no further attenuation was observed.

Possible modifications. This system could be modified easily to suit other applications.

In the present arrangement, an operator monitors the recorder continuously while the engine is running and sounds an alarm when a predetermined clearance is reached. An automatically controlled system could be arranged whereby the ratemeter output would be fed to a compensating mechanism that would correct for a change in signal.

Sensitivity could be optimized by considering such factors as source intensity, radiation energy, amount of absorber between source and detector, efficiency of detector and collimation.

Finally, a longer or shorter scanning time or additional points of measurement per scan can be gained by altering the mechanics of the system.

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Russians on Tour: U. S. Facilities Get the Once-Over

Nine top-ranking Russian nuclear scientists, headed by Vasily S. Emelyanov, Soviet nuclear program chief, spent 14 exhausting days on a coast-to-coast tour of the U. S.' chief atomic sights. It was a return visit after a McCone-led U. S. team toured Russia (NU, Nov. '59, 24). The Soviet group saw NS *Savannah*, the Shippingport, Fermi and Dresden reactors, toured the Argonne, Oak Ridge, Los Alamos, Brookhaven, Princeton Matterhorn, and Lawrence Radiation laboratories, the National Reactor Testing Station, and a uranium mine and mill, at Grants, N. M. Talks in Washington ended the trip.

Asked by NUCLEONICS at the end of his tour what had impressed him most, Emelyanov cited, in this order: the reactor development work by Argonne both at Lemont and Idaho, its scope and scale; Dresden ("very well engineered, its builders can be proud"); Fermi ("exceptionally well done, bespeaks a real scientific courage by those who undertook such a departure in reactor design"); HRE-2 ("particularly impressed me personally; I congratulate Dr. Weinberg, who loves this reactor very much, for pushing forward with this radical new possibility"); the fusion work at Princeton, and Brookhaven's 25-Bev accelerator.

RUSSIAN FACES on tour: they belong (from top) to Vasily S. Emelyanov, head of Main Administration for Utilization of Atomic Energy; Anatoliy P. Aleksandrov, mathematic physicist; Aleksandr I. Leipunsky, physicist; Nikolai A. Dollezhal, power and construction engineer; Andrei A. Bochvar, metallurgist and chemist; Igor N. Golovin, plasma physicist; Vladimir I. Veksler, high-energy physicist; Eugeni V. Piskarev, engineer and physicist; Gennadi L. Konstantinov, engineer.

IDAHO: Meyer Novick, bottom left, explains EBR-1 core; Emelyanov looks over his shoulder

LIVERMORE: Richard Post, top left, explains a plasma generator model

OAK RIDGE: Golovin checks a dial at TVA's Kingston Steam Plant

LIVERMORE: Stirling Colgate, left, explains Hard Core Pinch machine

ARGONNE: Fmelyanov reaches for Argonaut's scram button as McCone watches

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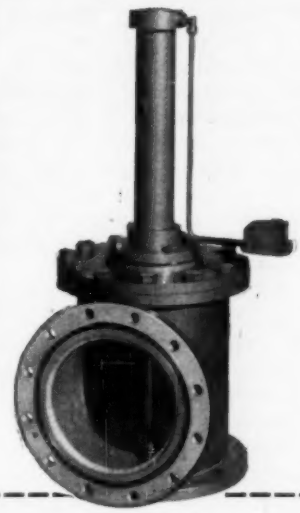

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Progress in Nuclear Energy —Metallurgy and Fuels, Vol. 2

H. M. FINNISTON and J. P. HOWE, editors (Pergamon Press, New York, 1959, 653 pages, $21)

Reviewed by R. W. Dayton, Battelle Memorial Institute, Columbus, Ohio

The intention of the "Progress in Nuclear Energy Series" is given as that of publishing authoritative review articles on all aspects of atomic energy. This second volume on metallurgy and fuels reviews the progress in the science and technology of fuel materials and fuel elements up to the end of 1957. More recent developments will be covered in Volume 3, which will also be published during 1959.

The book is divided into two major sections. Part I deals with basic materials while solid-state physics and physical metallurgy is covered in Part II. The articles on uranium, thorium, and plutonium in Part I concentrate on the reduction, purification, and melting of these materials. Uranium purification is discussed in two articles, one on electrolytic techniques for preparing very pure uranium and another on zone melting, applicable either to ordinary refining, or to reprocessing for fission-product removal. Other discussions of uranium deal with Belgian practice for production of uranium, and with a résumé of information about hydrogen in uranium. Two articles on thorium are concerned with its reduction, and two more with its arc and induction melting. The reduction of plutonium to the metal, or to a plutonium-containing alloy is described in two other sections. All of these articles are good; those on the extraction of thorium, and on the preparation of plutonium and plutonium alloys, are especially satisfying, with a good balance between the pertinent thermodynamic data and the practical details of extraction methods.

The properties and fabrication of the oxides of uranium and of thorium are discussed in two articles. While these articles are good ones, the one on urania is less useful because so much more information is available on this material today than when the article was written.

A large fraction of Part I is devoted to the technology of magnesium, zirconium, and beryllium cladding materials. The article on magnesium alloys relates French experience with magnesium alloys containing additives of zirconium and zinc, and compares the corrosion and mechanical properties of these materials with the British Magnox alloys. The articles on beryllium go into the extraction, the melting and casting, and the fabrication of the material. In the latter article there is an admirable treatment of the relation between fabrication variables, texture, and ductility of the fabricated product (an article in Part II summarizes what is known about preferred orientation in uranium, thorium, zirconium, and beryllium). The melting and welding of zirconium alloys are discussed in three articles. A fourth article on zirconium presents a comprehensive report on diffusion in the zirconium-uranium system.

The remaining articles in Part I deal with the technology of control materials and of dispersion fuels, and with the fabrication of fuel elements for specific reactors—Borax IV, EBWR, British gas-cooled reactors, and the SRE. The article on gas-cooled-reactor fuels is the best review of the British program that I have seen. The other articles on fuel fabrication proved less interesting, because the information has been published before, or because the fuel elements described have proved to be inadequate. [Perhaps a British reviewer would have a directly opposite viewpoint!]

The two concluding articles in Part I review information on nondestructive testing methods, and on wetting by liquid metals.

Discussions of the physical metallurgy of uranium, thorium, and plutonium appear in Part II of the book. Constitutional diagrams are given for the more important plutonium alloys, and for thorium and uranium alloys when these add appreciably to information already reported in Volume I of this series. There are two articles on transformations in uranium-base alloys —one on dilute alloys, the other on the metastable gamma-phase alloys. Another article presents some high-temperature mechanical-property data for uranium alloys.

Also in Part II are five articles on radiation effects in metals, in crystalline and glassy solids, and in graphite. These articles are among the high points of the book and, taken together, comprise one of the better compilations of information in this area. All of the articles are well written and attempt to relate the radiation effects observed to theory. Attention is confined, however, to nonfuel materials. The subject of fission-gas swelling is not treated, since the major developments in this area have occurred in the last two years.

Inevitably, a book of this sort has an uneven character, with outstanding material mixed with some which is not so outstanding. Technical advances have made some of the articles obsolete, and have focused attention on new problems whose importance was not appreciated when the material for this book was written.

Perhaps the major criticism one could make of this book is that, for a field like nuclear energy, a two-year interval between writing and publishing is too long. Such criticism applies only to the minor portion of the book. Most of the material is as useful today as when it was written, and the editors should be complimented on a judicious choice of subjects and authors for fulfilling the objectives of the book. Those who have serious interest in nuclear materials will find the book well worth what it costs.

Nuclear Electronics

Published by International Atomic Energy Agency (Vienna, Austria, 1959, 452 pages, $4)

Reviewed by L. Costrell, National Bureau of Standards, Washington, D. C.

This volume covers the first five sessions of the International Symposium on Nuclear Electronics held at the UNESCO House in Paris, September 16–20, 1958 under the sponsorship of the Commisariat a l'Energie Atomique and the International Union for Pure and Applied Physics. The Symposium was organized by the Societe Francaise Des Radioelectriciens. Papers were presented by scientists from France, Germany, Great Britain, Holland, Italy, Switzerland, and the United States.

The International Atomic Energy Agency has done a superb job in compiling the papers and the discussion in such readable form. About half of the articles are in English and the remainder in French. Inasmuch as there are nearly 50 papers, varying in

length from 350 words to 4000 words and averaging about 1600 words, many of the articles are quite sketchy. Nonetheless, the compilation does conveniently present a survey of what is going on in nuclear electronics throughout the western world. The authors are among the leaders in the field and the information presented represents current work of an advanced nature. The compilation is "must" reading for workers in the nuclear instrumentation field. It is unfortunate that an all-English version is not available. In the hope that the International Atomic Agency or the National Academy of Science (or even some group whose interest is more pecuniary) will take the hint, the reviewer hastens to add that he will be among the first in line for an all-English issue.

In the first session Durand and Habert discuss alternative types of slow neutron scintillators using enriched B^{10}. Koch, et al. give results of tests at Saclay on the effect of temperature on the characteristics of photomultipliers and scintillators. This work differs from earlier work principally in that the temperature coefficients have been determined as a function of the wavelength of the scintillations. Owen has extended the work that he reported in 1958 on the utilization of the variation of phosphor decay time for discrimination between particles of differing specific ionization.

Session II on radiation detectors using ionizing methods and gamma ray spectrometers opens with a discussion by Facchini of ionization chambers for energy measurements and "counter spectrometers" that use assemblies of gas and scintillation counters. Work at Saclay on the use of *np* junctions in germanium and silicon for detection of nuclear particles and for direct conversion of nuclear energy to electrical energy is reported by Bomal, et al. Mme. Koch presents data showing that highly purified noble gases can be used as scintillation detectors for nuclear radiation where short resolving time and non-saturation effects are desired. This talk evoked considerable interest and the article is followed by a lengthy discussion.

The session on fast electronic techniques is opened by Wiegand with a brief description of some of the fast electronics used with the Berkeley Bevatron, including the velocity-selecting Cerenkov counter. He also enters his plea for photomultipliers with reduced transit-time spread and for components better suited to nanosecond circuitry. Cottini, Gatti and Vaghi describe their fast vernier time analyzer. They are planning to work on an analyzer using nonlinear excitation of the resonant circuits so as to avoid the "sophistication" resulting from the use of linear excitation.

Duclos describes a chronotron designed for use as a fast neutron spectrometer. A resolution of 4.5×10^{-10} sec is obtained with two photomultipliers viewing a single plastic crystal, though no mention is made of the efficiency. Brisson, et al. present a high-speed coincidence circuit for high counting rates. Hornyak and Yoshiki describe a fast coincidence circuit that is an extension of a circuit developed by Dicke in 1947. Meunier presents a differential coincidence circuit with a maximum resolution that is essentially independent of the duration of the input pulses. Data taken with Cerenkov radiation incident on fast photomultipliers gives a count rate versus delay curve with a full width at half maximum of 6×10^{-10} sec.

Pieper describes the charge storage type of pulse-height analyzer being designed at Yale for use with pulsed accelerators. This instrument is similar in many respects to that under development at the National Bureau of Standards. Fiehrer and Pages describe a 10-channel stacked discriminator type of pulse-height analyzer utilizing novel circuitry and capable of a resolving time of less than ½ nanosecond. Pellegrini and Rispoli describe two high-speed vacuum-tube-type scalers of good stability. One uses binary stages coupled by cathode followers while the other uses a ring-of-five plus a binary stage to obtain a scale-of-10. Orman discusses the operation of pulse sampling oscilloscopes for observation of nanosecond pulses.

Gatti opens session IV on classical nuclear electronics with a brief discussion of recent developments in pulse amplifiers, scalers, pulse timing methods, and information storage. In another article, Gatti and Cottini describe a 200-channel pulse-height analyzer of the Wilkinson type. Another Wilkinson type analyzer described by MacMahon utilizes "dual step conversion" to reduce considerably the time required to route a pulse to the proper address in the memory.

French authors contributed the lion's share of the papers on reactor-control measurements. In the first article in this section, Weill presents an analysis of the control of a reactor by means of temperature changes. The paper by DeShong describes a procedure for determining the dynamic performance of a power reactor, using a wave analyzer developed at Argonne for this purpose. Larin and Van Rennes discuss the philosophy of reactor safety control, considering in turn (1) failure-to-safety circuits, (2) redundancy and coincidence circuits, (3) monitoring and test circuits, and (4) use of reliable components.

Dandurand examines the problem of automatic control of Saclay pile EL 3 and reviews the results obtained in practice. DiGiacomo reviews the control system for the gas cooled, graphite moderated, breeding reactor G 2. Jover reports on the automatic control system constructed for the swimming pool reactor of the Centre d'Etudes at Grenoble.

* * *

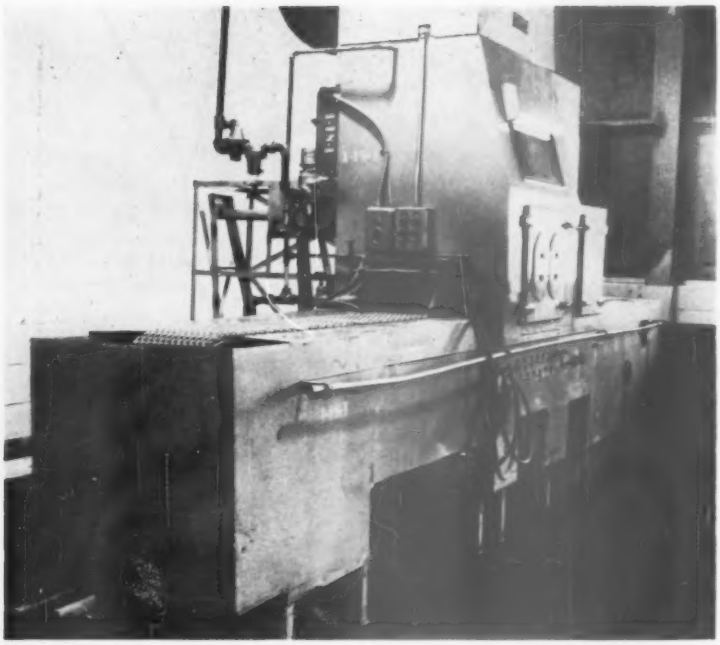
The reviewer gratefully acknowledges the assistance of John Mandel and Dr. Earl Mosburg in the translation of many of the articles.

Geneva '58 Proceedings*

Vol. 1, Progress in Atomic Energy (525 pages, $12.50), includes the conference program, opening and closing sessions, evening lectures and descriptions of the national exhibits. The bulk of the volume is taken up by the sessions on "The Future of Nuclear Power," "Supply and Training of Technical Personnel" and "Development of International Collaboration." "The Future of Nuclear Power" contains descriptions of national programs. The session on personnel points up the increasing attention that must be given to staffing these programs.

Vol. 14, Nuclear Physics and Instrumentation (491 pages, $17). Here are recorded the full proceedings of Sessions A-19 (Basic Physics in Nuclear Energy, Part 1) and A-18 (Nuclear Instrumentation and Techniques). In the first part are presented various papers on nuclear structure and nuclear energy levels. Theories of nuclear reactions and beta decay and experimental results on new isotopes are included here. The second part includes papers on neutron spectrometry, counters, coincidence analyzers, emulsion techniques, bubble chambers and certain other nuclear techniques. It is a valuable collection including some excellent reviews, though there will be few readers to whom both parts are equally useful.

* Other volumes were reviewed in the July through November issues of NUCLEONICS.



Wet-Blasting Unit

Compressed air provides thorough agitation of water and abrasive in the hopper of wet-blasting unit (above). Air jets in the hopper are spaced to ensure that a homogeneous mixture is always forced from blast gun. Abrasive compounds, specifically formulated for wet-blasting equipment, are mixed with wetting agent and emulsifier; rust inhibitor is also added. Microscopic glass balls, one of 14 different abrasives used, produce a particularly smooth finished surface. Aluminum oxide abrasive is also widely used for nuclear applications. Blasting units are fabricated of 304L stainless steel; they can be conveyerized (above) or left manual, with glove ports providing access to blast gun. Special units that can wet-blast radioactive and cold materials are located in more than a half-dozen nuclear facilities.—Pressure Blast Mfg. Co., Manchester, Conn.

Flexible Graphite Textile

Fiber or fabric such as rayon can now be graphitized by electrically heating it to about 5,400° F. Purity of resulting graphite material (above) exceeds 99.9%. Tensile strength at 4,500° F is about twice that at room temperature, and fabrics are unaffected by liquid N at −320° F.—National Carbon Co., 30 E. 42nd St., New York 17, N. Y.

High-Temperature Graphite

A new oriented-crystal graphite called Pyrographite withstands temperatures up to 6,700° F. It conducts heat 500 times better along its surface than through it. Densities up to 2.2 have been achieved, whereas densified graphites range from 1.7 to 2.0. Above 2,000° C, Pyrographite has strength-to-weight ratio five times greater than graphite. In highly erosive atmospheres such as reducing stream of high-velocity, high-temperature solids and gases, material has shown little erosion, whereas graphite breaks down. No permeation by He has been detected with standard mass-spectrometer detector even in 1–2-mil-thick films that had been heated to 2,500° C and recooled.—Raytheon Company, Waltham 54, Mass.

Laminated Graphite

Graphite fiber has been impregnated with heat-resistant phenolic resin to create exceptional heat resistance. Exposed to a 5,000° F flame, the material exhibited a burn-through rate of <0.0005 in./sec. Both lengthwise and crosswise tensile strength exceeds 10,000 psi.—Continental-Diamond Fiber Corp., Newark, Del.

Hydraulic Micropipetter

Hydraulic micropipetter serves as a microburet and precisely aliquots radioactive solutions. Samples from 0.001 ml to 1 ml can be measured.—Nuclear-Ohio, Inc., Bay Village, Ohio.

Remote Tukon Tester

Mechanical linkage through a control panel permits remote operation of all functions of a Tukon microhardness tester (above). Indenting loads in 1–3,000-gm and 1–10,000-gm ranges are used. Automatic cycle of load application is adjustable in the range from 33 sec to a max of 5 min. A turntable vise assembly can rotate the sample 360 deg in a horizontal plane. Series of optical relays bring image of illuminated microscope outside test cell.—American Chain and Cable Co., Inc., 929 Connecticut Ave., Bridgeport 2, Conn.

Disposable Plastic Outerwear

Head-to-toe protection from aerosol contamination is provided with a line of disposable plastic outerwear. Line includes wrist, elbow and shoulder-

length sleeves, various sized aprons and ankle to knee-length shoe covers.—Plasco Safety Products Co., P. O. Box 367, Springfield, Ohio.

Disposable Boots, Gloves

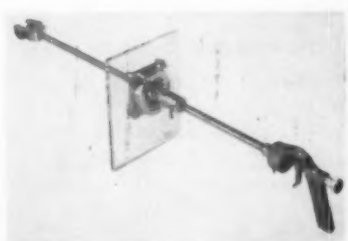
Disposable plastic boots and gloves are packaged in rolls of 50 and 100 items. Boots can be closed at top with paper clip or rubber band. Five-fingered gloves are available in 3 lengths and 3 sizes.—Plasticsmith, Inc., P. O. Box 1071, Pittsburg, Calif.

Knitted Shoe Slip-Ons

Washable knitted shoe slip-ons can be worn over street shoes. One size fits any shoe since special stretch Nylon yarn is used.—Blue Star Knitting, Inc., 1430-D N. Farwell Ave., Milwaukee 2, Wisc.

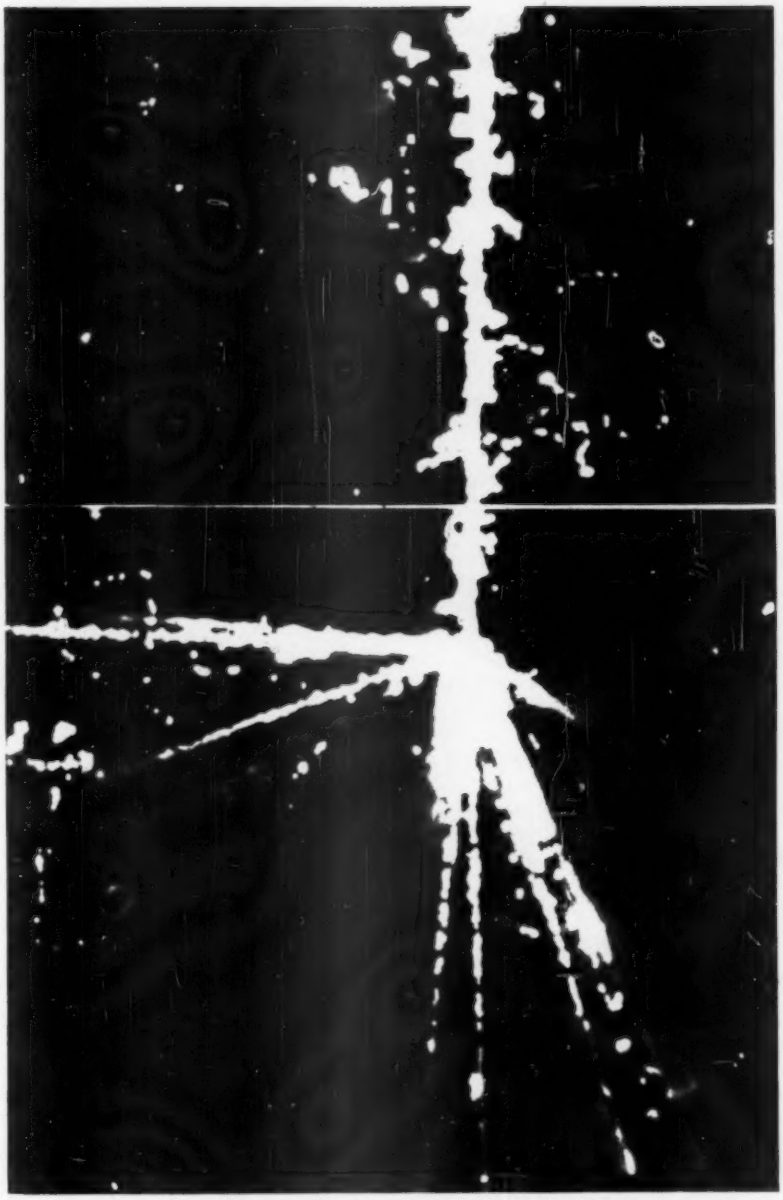
Lead Telluride Elements

Thermoelectric generator elements made of lead telluride are available in six standard sizes (above) for use in experimental and prototype applications. Generators built with the elements have delivered over-all efficiencies of 6% or more. Calculated thermal efficiency at matched load conditions under temperature differential of 1,000° F is 7.85%. Elements are supplied with prefinished hot junction surfaces and pretinned cold junction surfaces.—Minnesota Mining and Manufacturing Co., Dept. D9-401, 900 Bush Ave., St. Paul, Minn.

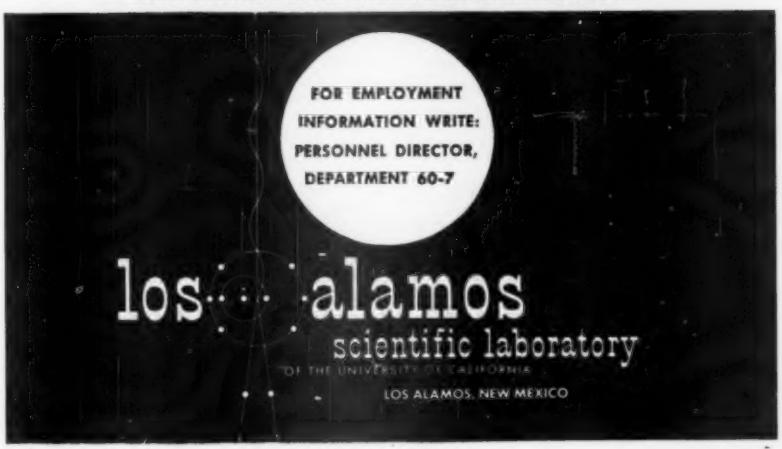


Vacuum Manipulator

Versatile manipulator (above) has 3-ft stainless-steel shaft that passes through double-pumped vacuum seals and can work in positive pressures and vacuum exceeding 10^{-6} mm Hg. Ball-joint action permits full motion through



BASIC RESEARCH AT LOS ALAMOS INCLUDES NUCLEAR PLATE STUDIES OF HIGH ALTITUDE RADIATION PHENOMENA.



90-deg cone. Special model for high-temperature work is available.—Scientific Engineering Labs., Inc., 1510 6th St., Berkeley 10, Calif.

Multichannel Gaging System

Low-cost multichannel gaging system has a single control and power unit which provide power for up to 10 probes. Multiple point recorder can record data of each station. System uses low cost, unshielded cable. Detector can be located up to two miles from station—Tracerlab, Inc., 1601 Trapelo Rd., Waltham 54, Mass.

Nonoverload Amplifier

Nonoverload linear amplifier has recovery time of <7 μsec for overload up to 200×, better than 20 μsec with 1,000× overload. Wide-band instrument also has good high resolution and gain characteristics.—The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Decimal Scaler

Decimal scaler has 1-μsec resolving time, total count capacity of 10^8 and preset count of 10^6. High voltage supply is continuously variable between 500 and 5,000 v.—Radiation Instrument Development Laboratory, Inc., 5737 S. Halsted St., Chicago 21, Ill.

Portable Oscilloscope

Transistorized battery-operated portable oscilloscope (above) can operate up to 3 hr on ten size D flashlight cells, up to 6 hr on rechargeable cells. It can also operate on 110 and 220 v, 50–800 cycles, and on 11–35 v d-c. Vertical passband is d-c to 5 mc, rise time is 0.07 μsec, and sweep range is 0.5 μsec to 0.5 sec/div in 19 calibrated steps.—Tektronix, Inc., P. O. Box 831, Portland 7, Ore.

Ultrasensitive Leak Detector

Leak sensitivity of 1×10^{-13} cm³/sec is featured in new helium mass-spectrometer leak detector (above). Sensitivity is achieved with two magnetic analyzers used in series; ions are accelerated from the first to the second. Ions that were gas-scattered in the first analyzer are resolved into separate peaks by the second. Refocusing of scattered ions produces a much sharper He peak. Adequate valves are provided to sectionalize the equipment, thus allowing spectrometer filament to be changed in minutes.—Crosby-Teletronics Corp., Vacuum Research Div., 54 Kinkel St., Westbury 4, N. Y.

Proportional Counting System

Model PC-3A proportional counting system counts H^3, C^{14}, Ca^{45} and S^{32}. System counts β radiation in presence of α without absorbers, and α in presence of β. Unit can be used as a scaler.—Nuclear Measurement Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

Ion Chamber

Analysis unit L-75D consists of ionization chamber and quartz fiber electrometer powered by self-contained, transistorized power supply.—The Landsverk Electrometer Co., 641 Sonora Ave., Glendale 1, Calif.

Data-Readout System

Model 44-7 add punch can be used with a multichannel analyzer to provide punched tape and/or adding machine tape readouts of stored data.—Radiation Instrument Development Laboratory, Inc., 5737 So. Halsted St., Chicago 21, Ill.

Scintillation Scanner

Low-cost scintillation scanner has contrast circuit emphasizing small relative differences in radioisotope concentration and minimizing effect of background radiation on the scan. Only peak energy of selected isotope is re-

corded. Three-in. lead detector shield eliminates halo.—Picker X-Ray Corp., 25 S. Broadway, White Plains, N. Y.

Potentiometer Recorder

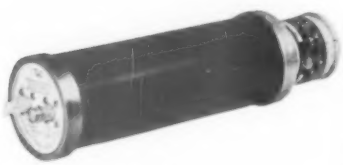
Dual channel strip chart recorder has both pens traversing full width of 5-in. chart. Zero can be set anywhere on chart; range is adjustable from 0–9 mv to 0–100 mv. Chart-speed options range from ½ to 8 in./hr.—Varian Assoc., Instrument Div., Palo Alto, Calif.

Tritium Monitor

Model 34 tritium monitor detects 10^{-12} c of H^3/ml of air (0.04 mrep/hr.). Four ranges are provided corresponding to about 2.0, 0.2, 0.02 and 0.002 rep/hr. Drift <0.00004 rep/hr.—Applied Physics Corp., 2724 So. Peck Rd., Monrovia, Calif.

D-C Power Supply

Power supply using selenium rectifiers immersed in high-grade insulating oil is rated 40 kv at 1 ma and 35 kv at 5 ma. Ripple is 0.5%/ma.—Del Electronics Corp., 521 Homestead Ave., Mt. Vernon, N. Y.



Detector with Preamp

Scintillation detector with integral transistorized preamplifier (above) can drive up to 500 ft of cable. Rise time is 0.15 μsec; output-pulse duration is set at 1 μsec; 0.55 ma is required at 1,000 v.—Technical Measurement Corp., 441 Washington Ave., No. Haven, Conn.

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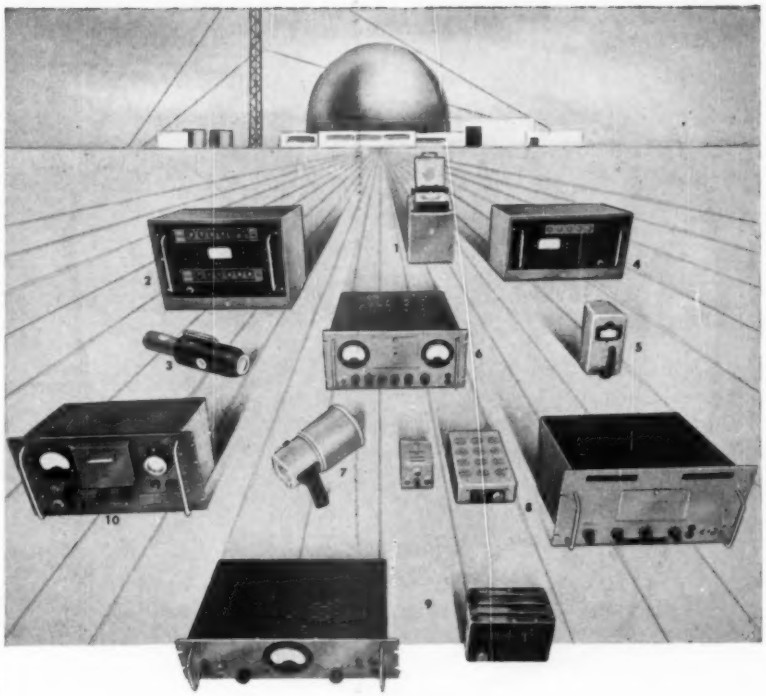
Direct-counting linear counting-rate meter (above) has a 10–50,000-cps range with nine intermediate linear ranges from 0 to 5,000 cps. Decade



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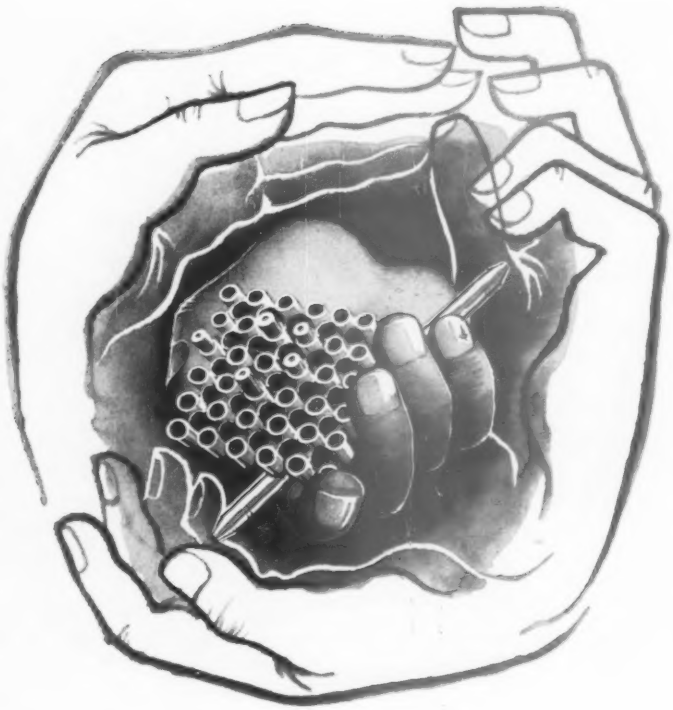

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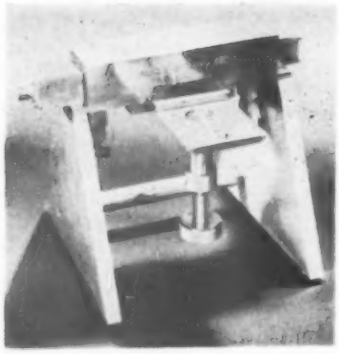
Pulsed Neutron Generator

Basic components of a low-cost, pulsed neutron generator (above) are high-voltage pulse transformer, deuterium neutron target and acceleration tube, and remote-control electronic rack. Higher-priced models have mechanical or diffusion pump, cold trap and manifold in open frame.—Atomic Labs, Inc., 3086 Claremont Ave., Berkeley 5, Calif.

Solar Furnace

Searchlight-type solar furnace creates temperatures to 6,741° F with heat densities up to 365 calories/cm²/sec. Furnace permits great flexibility and control in establishing environmental conditions, and is equipped with automatic tracking system and remote controlled sample positioner and temperature adjustment.—Waltham Precision Instrument Co., 221 Crescent St., Waltham 54, Mass.



Alpha Proportional Counter

Continuous gas flow alpha proportional counter (above) can measure alpha radiation levels as low as 10 disintegrations/min in presence of beta background up to 10^8 disintegrations/min. Anode is a 0.002-in. stainless steel wire extending length of chamber providing a nearly symmetrical electrical field.—Nuclear-Ohio, Inc., Bay Village, Ohio.

Chrome Plating

Electrolytic hard-chrome plating on base metal produces dense, fissure-free bond of alloy-like strength. A variety of odd configurations can be plated because of superior throwing power of the process.—Gits Bros. Mfg. Co., 1848 S. Klibourn Ave., Chicago 23, Ill.

Ultrasonic Welder

Instrument-type ultrasonic welder (above) welds small parts and delicate assemblies without melting or fusion since no electric current passes through welded parts. Many difficult-to-join metal combinations are handled, such as contacts between silicon or germanium and aluminum or gold. Other dissimilar-metal combinations can also be joined. Ultrasonic-welder line includes 100- (above), 300-, 2,000- and 4,000-watt models.—Aeroprojects, Inc., West Chester, Pa.

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LITERATURE AVAILABLE

Multichannel scaler-analyzer. 4 pp.; Radiation Counter Laboratories, Inc., 5121 W. Grove St., Skokie, Ill.

Transistorized nuclear instrumentation. Nos. DS 400A to 403A; Bendix Aviation Corp., 3130 Wasson Rd., Cincinnati 8, Ohio.

Radiation monitoring instruments. 4 pp.; Universal Transistor Products Corp., 17 Brooklyn Ave., Westbury, L. I., N. Y.

Shielded thin-window counter. 2 pp.; Atomic Accessories Inc., 244-02 Jamaica Ave., Bellerose 26, N. Y.

256 channel analyzer. 15 pp.; Nuclear Data Inc., 145 N. Washington St., Wheaton, Ill.

Area monitoring systems. 2 pp.; Riggs Nucleonics Corp., 717 N. Victory Blvd., Burbank, Calif.

Medical & clinical instruments. 32 pp.; Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

Nucleonic instrument catalog. 20 pp.; Etelco Limited, 22 Lincoln's Inn Fields, London, W. C. 2, England.

Nuclear instrumentation. 33 pp.; Nuclear Corporation of America, 2 Richwood Place, Denville, N. J.

Nuclear instrumentation. 12 pp.; Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Neutron dosimeter. 20 pp.; W. B. Johnson & Associates, Inc., P. O. Box 415, Mt. Lakes, N. J.

Radioactive tracers. Bulletin 650; U. S. Nuclear Corp., P. O. Box 208, 801 N. Lake St., Burbank, Calif.

Radiochemicals. Schedule E, 20 pp.; Nuclear-Chicago Corp., 333 E. Howard Ave., Des Plaines, Ill.

Standarized lead shielding. Atomic Accessories, Inc. 244-02 Jamaica Ave., Bellerose 26, N. Y.

Nuclear irradiation services. 8 pp.; General Electric Co., Atomic Power Equipment Dept., 2151 S. First St., San Jose, Calif.

Radioactivity training, experiments. 114 pp.; Nuclear-Chicago Corp., 333 E. Howard Ave., Des Plaines, Ill. (For educators only.)

Columbium, tantalum, vanadium. 5 pp. **Fuel element, heat exchanger tubing.** Bulletins STC-102 and 104, 8 pp.; Superior Tube Co., Norristown, Pa.

Guide to specialty steels. 40 pp.; Carpenter Steel Co., Reading, Pa.

Corrosion resistant tubing. 4 pp.; Bridgeport Brass Co., Bridgeport 2, Conn.

Filter pump units. 7 pp.; Sethco Manufacturing Corp., 2284 Babylon Turnpike, Merrick, N. Y.

Turbine-type pumps. 8 pp.; Aurora Pump Div., New York Air Brake Co., Loucks St., Aurora, Ill.

Gas bearings. 10 pp.; Armstrong Siddeley Motors Ltd., Reactor Component Div., Coventry, England.

High-temperature ovens. Catalog C-3, 26 pp.; Modern Laboratory Equipment Co., Inc., 1811 First Ave., New York 28, N. Y.

Epoxy adhesives, sealants, coatings. 36 pp.; H. B. Fuller Co., St. Paul 2, Minn.

Ultrasonic cleaning primer. 12 pp.; National Ultrasonic Corp., 111 Montgomery Ave., Irvington 11, N. J.

Copper lined shielding window. 2 pp.; Research Equipment Co., P. O. Box 127, Glen Ellyn, Ill.

Laboratory-fume-hood selection. 15 pp.; Kewaunee Manufacturing Co., Adrian, Mich.

Embossed plastic radiation signs. 1 p.; Ad-O-Plastic Co., P. O. Box 474, Woodbridge, N. J.

Scanning, print & plot spectrometers. Models SS-1 and ASP-1ADR. **Print & plot scaler.** Model ADRS2-5; Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Flow regulator operation. 4 pp.; W. A. Kates Co., Deerfield, Ill.

Radiochemicals. 1 pp.; Schwarz BioResearch, Inc., Mount Vernon, N. Y.

INDUSTRY NOTES

• **High Voltage Engineering** has established a West Coast sales and service center at Redwood City, Calif. In charge is sales engineer David R. Kneeland.

• Shareholders will vote Jan. 12 on a proposed merger of **Bell & Howell** and **Consolidated Electrodynamics Corp.**, Pasadena, Calif. Under the proposal as approved by directors of both firms Consolidated would operate as a Bell & Howell subsidiary.

• AEC has cracked down on five more uranium mills accused of violating its safety regulations (NU, Sept. '59, 17). Ordered to file by Nov. 30 a "full statement" of steps taken to comply with the rules (radiation exposure limits for air and water) were: **Union Carbide Nuclear, Rare Metals Corp. of America, Dawn Mining, Gunnison Mining and Mines Development.**

• **Varian Associates** is establishing a marketing and research subsidiary in Switzerland—**Varian A. G.**

• Wyoming's fourth uranium mill, the **Federal-Radorock-Gas Hills Partners** plant 50 mi east of Riverton, has come on stream only six months after construction start. Minimum rated capacity is 522 tons U ore/day.

• Two Pacific Northwest uranium firms have challenged AEC's U-purchase program. In a suit filed at the U. S. Court of Claims, **Northwest Uranium Mines, Inc.**, and **Silver Buckle Mining Co.** protested that they were frozen out of the program after developing extensive ore reserves under AEC encouragement. AEC abruptly halted new purchase commitments two years ago (NU, Jan. '58, 23), but has since taken some steps to ease the pain for those then outside the program.

• AEC has extended to June 30, 1965 (or any earlier date by which deliveries are complete) its uranium-purchase contract covering the Shiprock, N. M., mill of **Kerr-McGee Oil Industries.** The mill processes 300 tons U ore/day, producing U_3O_8 and vanadium.

• **Cooper Range Co.** has acquired a substantial interest in **The Alloyd Corp.**, research-and-development supplier to AEC and others on high-temperature metals, etc.

NEW BUSINESS. Environmental survey for the High Temperature Gas Reactor, to be built on the grid of Philadelphia Electric Co., has been assigned to **Nuclear Science and Engineering.** Reactor site is at Peach Bottom, Pa., southwest of Philadelphia on the Susquehanna River. . . . **Jordan Electronics div.** of **Victoreen Instrument** has been given a $381,430 contract to supply its IM-108 radiacmeter (for detection and measurement of radiation) to the Army Signal Corps; this latest contract supplements an earlier one for $479,071. . . . **Tracerlab** has been awarded a $100,000 contract covering a radiation monitoring system for the Enrico Fermi reactor near Monroe, Mich. . . . Under another $100,000 contract, **Pratt & Whitney** is investigating heat-transfer potentialities of a number of materials for the National Aeronautics and Space Administration; the materials are under consideration for a nuclear-electric generating system.

FINANCIAL. $2.5-million is being raised by **Victoreen Instrument** via an offering of 6% convertible subordinated debentures, due in 1974; $1,850,000 would go to retire a bank loan, the balance added to a general fund. . . . **Beryllium Corp.** quadrupled earnings during the first nine months this year; income was $1,147,430 (92¢/share) on sales of $15,646,229, against $275,729 (22¢/share) on sales of $10,245,075 in the same 1958 period. . . . **Olin Mathieson** cited "increased revenues from nuclear fuel operations" as a factor in sharply higher earnings during the quarter ended Sept. 30; profit was 69¢/share, against 15¢ for the '58 period. . . . **Lithium Corp.** reported a slight increase in earnings for the first nine months over the same '58 period —$647,901 (70¢/share), against $645-867 (69¢); sales were down 2% to $8,259,731. . . . **High Voltage Engineering** expects a 25% increase in earnings this year over the '58 figure of $1.12/share; order backlog was reported near $10-million, compared with expected '59 sales of $7-million.

AGENCY NEWS. New sales representative for **Tracerlab's** Industrial Products div.—in the Pittsburgh, Buffalo and Cleveland areas—is **R. L. Holliday Co.**; the firm will handle beta gages and radiography systems.

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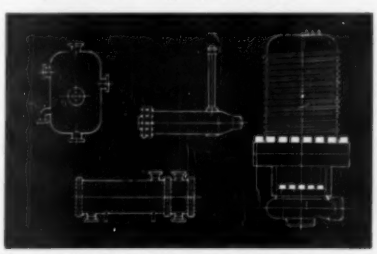

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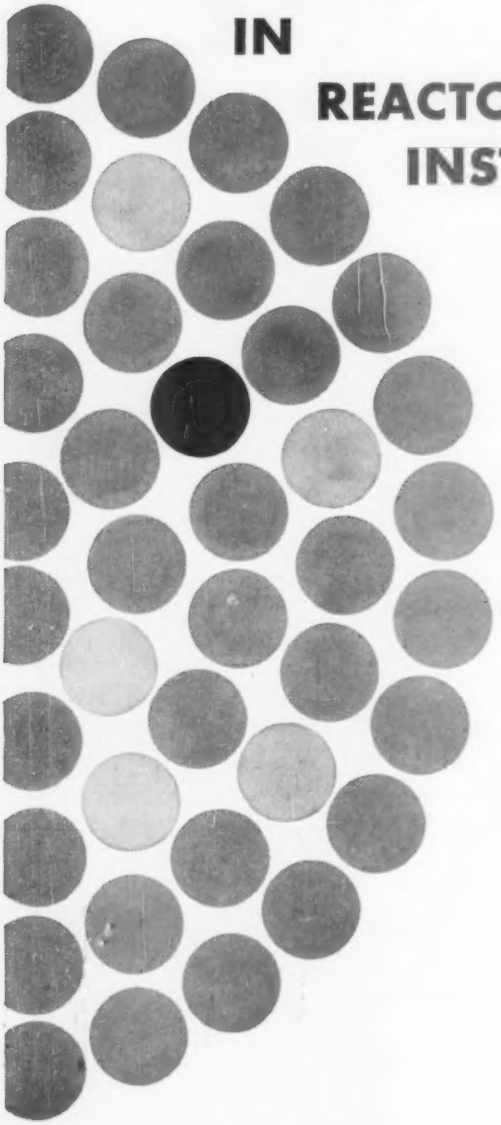

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NUCLEAR CALENDAR

Jan. 12–16—16th Annual Technical Conference, Society of Plastics Engineers, Chicago (*Conrad Hilton*). Several papers on radiation. Contact SPE, 65 Prospect St., Stamford, Conn.

Jan. 15—Symposium on Nuclear Education, sponsored by Baird-Atomic and two subsidiaries, Atomic Associates and Atomic Accessories, New York City (*Statler*). Speakers include officials of AEC and National Science Foundation and representatives of educational institutions. Contact Symposium Committee, Baird-Atomic, 33 University Rd., Cambridge 38, Mass.

Jan. 18–20—Seminar on hazards and insurance requirements of nuclear risks, sponsored by American Management Assn., New York City (*Astor*). Contact Seminar Registration, AMA, 1515 Broadway, New York 36, N. Y.

Jan. 27–28—Sanitary Engineering Conference on Radiological Health Aspects of Water Supply, sponsored by Illinois Public Health dept. and Civil Engineering dept., Univ. of Illinois, Urbana, Ill. (*University's campus*). Contact Wm. J. Downer, assistant chief sanitary engineer, Dept. of Public Health, Springfield, Ill., or Ben B. Ewing, Dept. of Civil Engineering, Univ. of Illinois.

Feb. 2—Meeting of New York Section, Society for Applied Spectroscopy. Sessions on handling of radioactive samples for emission spectroscopy and spectroscopic properties of photographic emulsions. Contact Paul Lublin, Sylvania Research Laboratories, Bayside, N. Y.

Feb. 3–5—Western Industrial Isotopes Conference, sponsored by Univ. of California, Stanford Research Institute and AEC, San Francisco (*Univ. of California Extension Center*). Contact Dept. of Conferences, U. C. Extension, 2451 Bancroft Way, Berkeley.

Feb. 3–5—Western Industrial Isotope Conference, San Francisco, Calif., sponsored by AEC, Univ. of California and Stanford Research Institute. Contact Prof. Lawrence M. Grossman, Univ. of California, 2451 Bancroft Way, Berkeley, Calif.

Feb. 10–11—Symposium on Gas-cooled Reactors, sponsored by Franklin Institute and Delaware Valley Section, American Nuclear Society, Philadelphia. To cover both U. S. and U. K. programs and include a British speaker at banquet Feb. 10. Contact Francis L. Jackson, FI, Philadelphia 3.

Feb. 11—AEC Information Meeting on Aircraft Nuclear Propulsion, Oak Ridge National Laboratory, Oak Ridge, Tenn. Contact R. A. Charpie, ORNL, P. O. Box Y, Oak Ridge.

Feb. 14–18—Annual Meeting of Ameri-

can Institute of Mining, Metallurgical and Petroleum Engineers, New York. Contact AIMMPE, 29 W. 39th St., N. Y. 18, N. Y.

Feb. 25–26—7th Scintillation Counter Symposium, Washington, D. C. (*Shoreham*). Contact G. T. Reynolds, Princeton Univ., Princeton, N. J.

March 18–19—Annual Meeting of Southeastern Chapter, Society of Nuclear Medicine, Oak Ridge, Tenn. Abstract deadline is Jan. 15. Contact Granville Kyker, ORINS Medical div., Oak Ridge.

March 23–24—Symposium on Optical Spectrometric Measurements of High Temperatures, sponsored by Applied Science Laboratories of Univ. of Chicago, Jarrell-Ash Co. and National Science Foundation, Chicago (*Univ. of Chicago*). Program includes papers on plasma. Contact Frederick Brech, c/o Laboratories for Applied Science, Univ. of Chicago, 6220 S. Drexel Ave., Chicago 37, Ill.

March 29–31—22nd Annual American Power Conference, sponsored by Illinois Institute of Technology and several societies and schools, Chicago (*Sherman*). Contact R. A. Budenholzer, Mechanical Engineering dept., IIT, 3300 Federal St., Chicago 16.

March 30–31—Workshop on Industrial Uses of Radioisotopes, co-sponsored by Connecticut Power & Light, Hartford Electric Light, Housatonic Public Service, United Illuminating, AEC and Yale Univ., New Haven, Conn. (*Yale*). Contact E. B. Haskell, United Illuminating, New Haven 6.

April 3–8—6th Nuclear Congress, New York City (*Coliseum*). Includes 6th Nuclear Engineering & Science Conference, 8th Atomic Energy in Industry Conference and 6th International Atomic Exposition. Contact E. B. Gunyou, Curtiss-Wright Corp., Princeton, N. J.

Apr. 19–22—International Symposium on the Metallurgy of Plutonium, Grenoble, France. Sponsored by French Society for Metallurgy. Contact Max Dupont, 25 rue de Clichy, Paris 9, France.

May 9–13—Instrument Society of America, San Francisco. For papers on measurement and control instruments contact Martin E. Kantor, c/o General Atomic, P.O. Box 608, San Diego 12, Calif.

June 12–15—Annual Meeting of American Nuclear Society, Chicago (*Palmer House*). Contact Octave J. DuTemple, 86 E. Randolph St., Chicago 1.

June 23–24—2nd Youth Conference on the Atom, Univ. of Michigan, Ann Arbor. Contact Bozell & Jacobs, 2 W. 45th St., N. Y. 36, N. Y.

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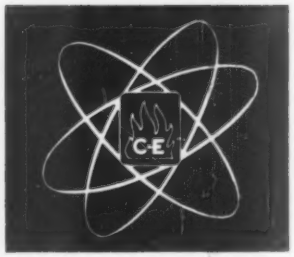

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NUCLEAR CAMPUS

CAMPUS FACILITIES. Construction permits have been issued by AEC for campus reactors at **Virginia Tech** and **Univ. of California at Los Angeles** (NU, Dec. '59, 224). . . . AEC also announced it was ready to issue construction permits for three other campus reactors (notice of proposed issuance routinely precedes issuance of the permit by a few weeks). **1. Univ. of Missouri's School of Mines and Metallurgy** has ordered a 10-kw pool-type reactor from Curtiss-Wright; the $223,800 project is scheduled for completion by May 31. **2. Stanford Univ.** has ordered a 10-kw pool-type reactor from General Electric; estimated cost is $175,000. **3. Worcester Polytechnic Institute** has ordered a 1-kw pool-type reactor from GE for completion by early this month; estimated cost is $167,000. All three reactors are being purchased with the help of $150,000 grants from AEC. . . . **Univ. of Missouri's College of Engineering** has expanded its nuclear-engineering facilities with the installation of a natural-uranium subcritical assembly, plus related radiation-measuring equipment. AEC contributed $35,337 to the project. . . . Round total of $400,000 in government and industry contracts—including one each from AEC and Sandia Corp.—have been given **Stevens Institute** for development of techniques in the cold casting of powdered metals. The work has promise for fuel elements and high-temperature materials.

PLASMA PHYSICS. The Ford Foundation has given $205,000 to **Princeton Univ.** for the training of research workers in plasma physics. The Foundation indicated it was particularly interested—via this huge grant—in supporting a growing research effort on controlled fusion.

COURSES. The U. K.'s Harwell Reactor School is offering its third international course in the **control and instrumentation of reactors,** Feb. 1–12, and the fourth course May 23–June 3. Harwell is also offering a special reactor course for **senior technical executives** May 9–20. Contact the Principal, Reactor School, A.E.R.E., Harwell, Berkshire, U. K.

On a continuing, periodic basis, Magnaflux Corp. is offering a one-week course in **nondestructive testing** at its Chicago plant, 7300 W. Lawrence Ave., Chicago 31. Fee is $100.

NEWSMAKERS

Tracerlab has named **Harlan C. Shaw** to the Physics Development group of its Western div. Shaw, who joined Tracerlab from the Lawrence Radiation Laboratory (working primarily on proton bombardment of beryllium, aluminum and copper), will assist Physics Development chief **Robert M. Main**, on proposals for the National Aeronautic and Space Administration.

A Defense dept. scientist, **Frank H. Shelton** of the Defense Atomic Support Agency, has joined the staff of Kaman Nuclear div. of Kaman Aircraft Corp. Shelton coordinated nuclear weapons tests in Nevada and the Pacific during his 4-years at the Pentagon.

Jack Crump, a radioisotope gaging specialist, has left Industrial Nucleonics to join Nuclear-Chicago. Crump was assigned to the new Industrial div., where he will be responsible for design of new industrial control instrumentation using isotopes.

George F. Leland of Knolls Atomic Power Laboratory has been named manager of power plant engineering for the Submarine Advanced Reactor (SAR). He will direct all activities involving the control, instrumentation, mechanical and fluid system, and equipment design for the *Triton* reactor and its prototype at West Milton, N. Y. **Arthur E. Powers** has joined the KAPL staff as a physical metallurgist in the Materials Development Operation.

Leland

John S. Kemper, on loan from Philadelphia Electric to Power Reactor Development Co., has been named shift supervisor for the Enrico Fermi fast breeder reactor.

J. H. Rubin, AEC Savannah River Operations Office, has been appointed liaison officer for the U. S.-Canadian exchange program on the technology of heavy-water power reactors. He has been assigned to AEC's Division of International Affairs, which, in turn, has assigned him to the AEC Liaision Office at Atomic Energy of Canada, Chalk River. However, his office will be in Toronto. Another Savannah River official—**Joel V. Levy**, director of the Industrial and Technical Services div.—has taken on the management of the Canoga Park, Calif., Area Office, reporting to the Chicago Operations Office. He will administer AEC contracts with Atomics International.

Joseph Ferrante, former vice-president of the defunct Tobe Deutschmann Corp. (NU, Nov. '59, 31), has been appointed director of research in dielectrics at the Cornell-Dubilier research lab being established in the old Deutschmann plant, Norwood, Mass. Ferrante-designed capacitors have been used in the controlled-fusion program.

Ferrante

Wayne P. Brobeck, vice-president of Ionics, Inc., and **Savery F. Coneybear**, director of new products development at Colgate-Palmolive Co., have been elected directors of Astra, Inc.

The Atomic Industrial Forum elected three new directors at its annual meeting in November: **Roy M. Casper**, vice-president of Allis-Chalmers; **Lee J. Davenport**, president, Sylvania-Corning Nuclear; and **Ernest H. Wakefield**, president, Radiation Counter Laboratories.

Glenn T. Seaborg, nuclear scientist, Nobel Prize winner and chancellor of the Univ. of California, Berkeley, has been given the Enrico Fermi Award for 1959. He was selected by AEC's General Advisory Committee for "discoveries of plutonium and several additional elements and for leadership in the development of nuclear chemistry and atomic energy." The award includes this foregoing citation, a medal and $50,000. Seaborg is the fourth recipient (the others: Fermi, John Von Neumann and E. O. Lawrence).

Seaborg

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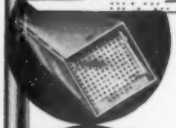

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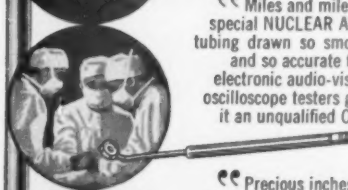

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NEWSMAKERS

Department starts on page 137

Alamos Scientific Laboratory, has joined the division as a staff scientist; **A. O. Mooneyham,** former chief of nuclear design and operations at Convair, has been named manager, Nuclear Projects dept.; and **Milton M. Weintraub,** formerly of Radioplane, has been named manager, Control Engineering dept. The Nuclear System div. is primarily concerned with development of a nuclear-ramjet engine (Project Pluto).

Clark Vogel, deputy director of AEC's Division of International Affairs, has left the Commission to join the legal staff at Martin Co., where he will devote most of his time to cooperative agreements under negotiation with foreign firms. He is not expected to work directly on nucleonics matters. Martin's Nuclear div. has brought in **Mostafa B. Talaat,** an Egyptian-born engineer from Carrier Corp., where he specialized in direct conversion, including design of a proposed 5-kw thermoelectric generator for the Navy. Talaat will direct all research and development in direct conversion at Martin Nuclear, with emphasis on thermoelectric, thermionic and magnetohydrodynamic systems.

Vogel

Talaat

Robert A. Charpie, assistant director of Oak Ridge National Laboratory, has been named secretary to AEC's General Advisory Committee.

An alumnus of the aircraft nuclear propulsion (ANP) project at General Electric has joined Beryllium Corp. as section chief in charge of new-product development. **Raymond Cooperstein** was principal engineer for high-temperature inorganic chemistry in GE's ANP staff.

J. D. Graves, a long-time radiation physicist, has been appointed acting general manager at the Alexandria, Va., div. of American Machine & Foundry Co. Graves has held important radiation posts at the Naval Research Laboratory, Stanford Radiation Laboratory and Naval Radiological Defense Laboratory.

Everett P. Blizard, director of the Neutron Physics div., Oak Ridge National Laboratory, has been appointed editor of the technical journal of the American Nuclear Society—*Nuclear Science and Engineering.* He succeeds **James R. Beckerley** (NU, Sept. '59, 158), who has joined the International Atomic Energy Agency to edit a new technical journal.

New chief of the AEC Security Branch at Los Angeles is **Sherman H. Sullivan,** former chief of the administrative section, Las Vegas office. His predecessor, **Fred W. Hohner,** has taken over the Las Vegas Branch.

George E. Kidd has been named head of the Mechanical Engineering div. at General Atomic's John Jay Hopkins Laboratory. He had been assistant chief engineer, Air Reduction Co.

Cy Ostreicher and **Robert Bruns** have been promoted to manager and assistant manager for sales, AMF Atomics.

Engineer **Thomas V. Wambach** has joined the Nuclear Power dept., Allis-Chalmers. He is a recent graduate of Marquette Univ.

Frederick E. Crever has been named to fill a new post—long-range planning—at GE's Atomic Products div. Crever had been a technical consultant to the division since last year, when he left his post as manager of Knolls Atomic Power Laboratory. The division includes the Atomic Power Equipment dept., Hanford Atomic Products operation and the Aircraft Nuclear Propulsion dept.

Crever

The Atomic Industrial Forum has named **G. E. (Ted) Brown** to its staff as manager for standards and radiation controls. Brown was a member of the staff of the Joint Committee on Atomic Energy for four years.

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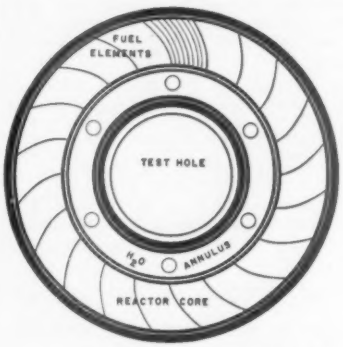

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finding the needle in a nuclear haystack

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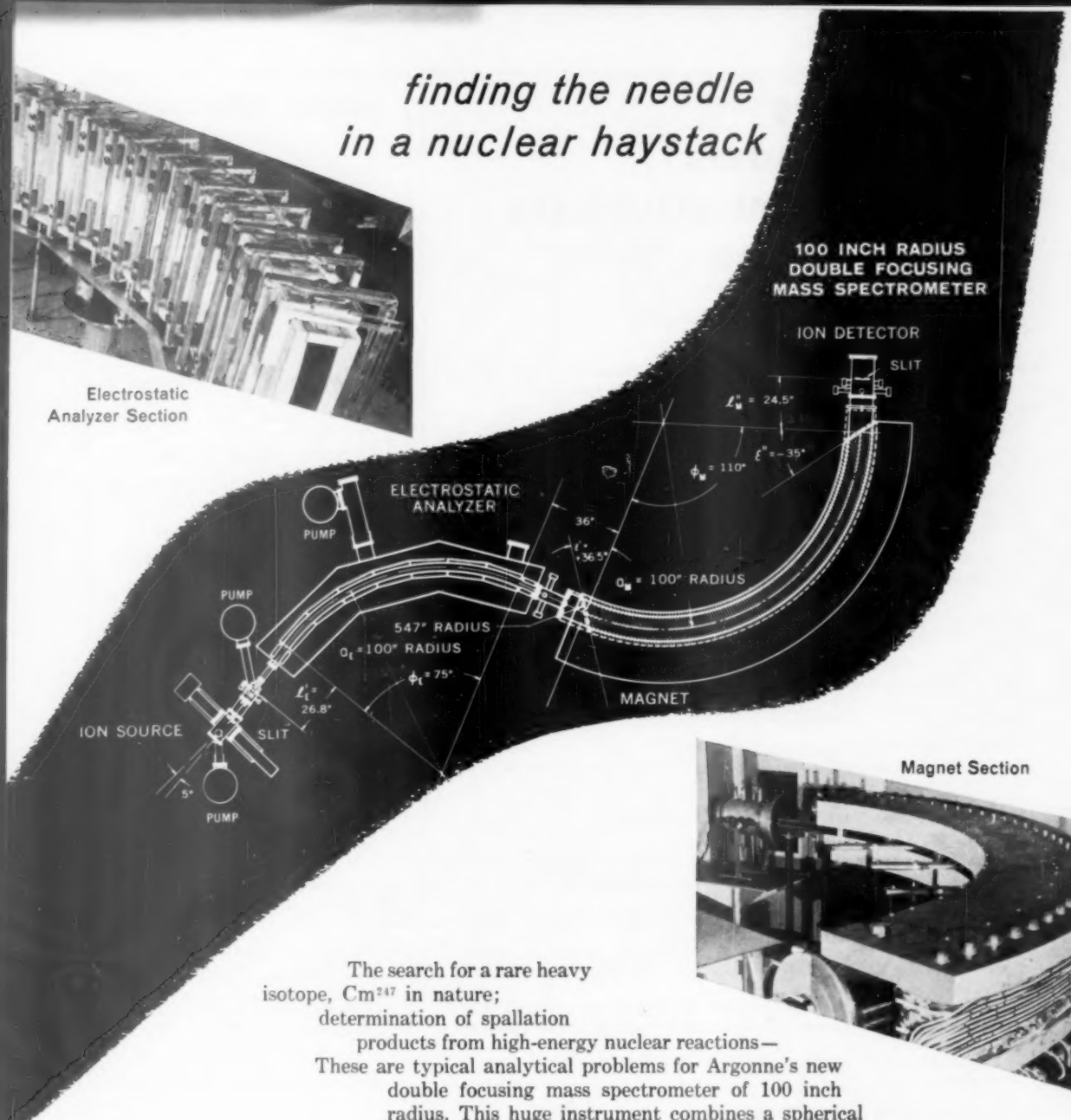

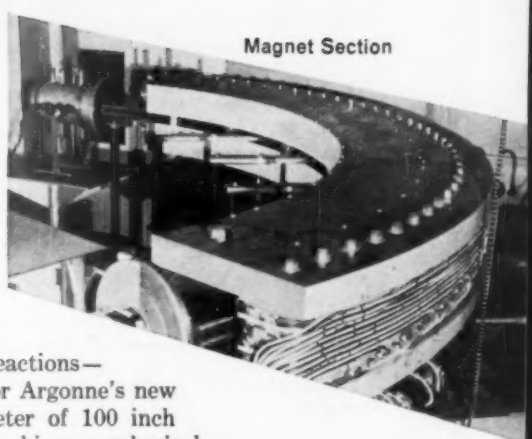

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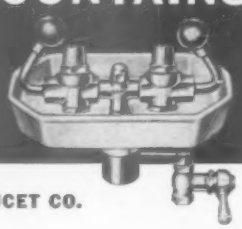

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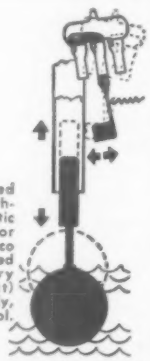

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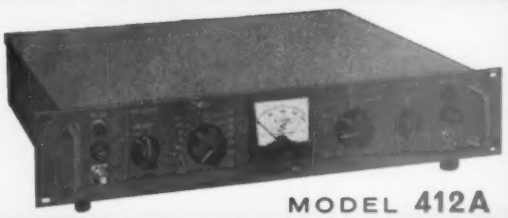

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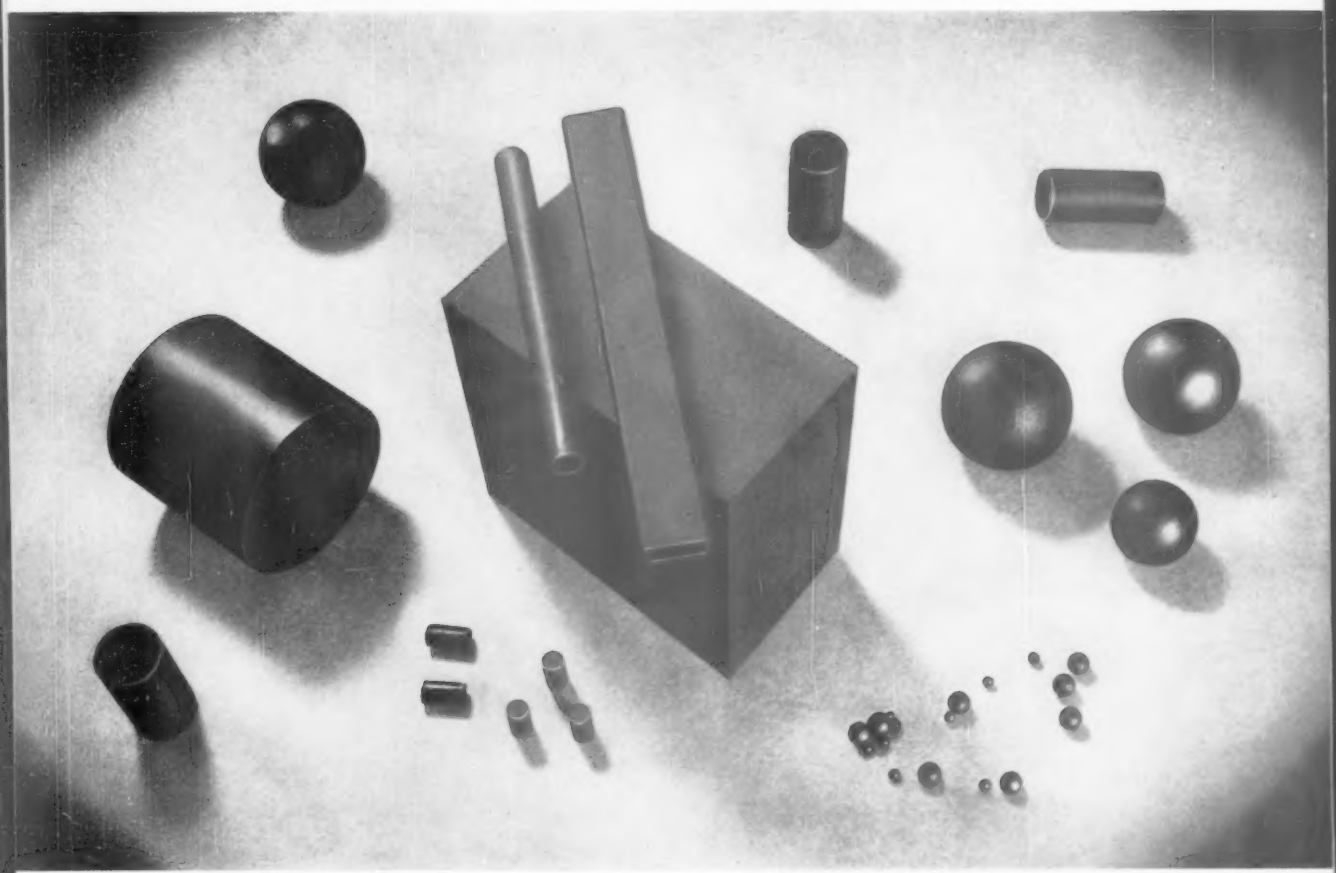

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